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BIM Implementation in Architecture Firms

Interviews, case studies and action research used to build a method that facilitates implementation of BIM processes and tools

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Building Information Modeling/Management (BIM) is an emerging technological and procedural shift within the AEC industry. In this paper, we describe how we used interviews, case studies and action research to collect information on how implementation of BIM is made in architecture firms. Hypotheses on what facilitates BIM implementation in these firms are drawn.

Keywords: *BIM implementation, architecture firms, method, action research, interviews, case studies*

INTRODUCTION

Building Information Modeling/Management (BIM) is a process that improves each facility's lifecycle phase, design and construction included, using standardized human and machine-readable information. It is often described as an emerging technological and procedural shift within the Architecture, Engineering and Construction (AEC) industry. But implementing BIM tools, workflows and protocols requires a lot of resources and impact everyday practice of firms: BIM is as a disruptive technology (Eastman 2008).

BIM adoption has, however, increased significantly over the last few years (Smith 2014) and many countries encourage BIM Diffusion by different policy actions. Since 2014, "member States [of the European Union] may require the use of specific electronic tools, such as of building information electronic modeling tools or similar, for public works contracts and design contests" (European Parliament 2014).

BIM nonetheless struggles to be integrated in practices of firms of the AEC sector in France. It has often been noticed that innovation diffusion is slower in the AEC sector than in other industries, partly because of the important part of Small and Medium-sized Enterprises (SMEs) (Turk 2000). SMEs are enterprises that employ less than 250 employees (INSEE 2018))

Architects are at the heart of the construction process, and are very often at the origin of the first digital mock-up of the project that is completed by other actors of the project. In France, 93% of architecture firms who employ at least 1 person are micro enterprises. (Microenterprises employ less than 10 persons. It is subcategory of SME (INSEE 2018))

Implementation guides and standards are rare and generally not adapted to SMEs (Hochscheid et al. 2016), who point lack of government help and public policy (Bataw et al. 2014; Poirieret al. 2015), lack of clarity in the adoption process and the lack of procedural implementation standard (Hosseini et al. 2016).

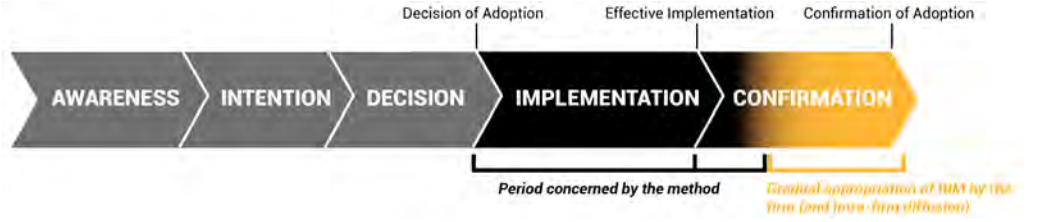


Figure 1
The proposed method (in black, during implementation step and the beginning of the confirmation step)) positioned on the BIM Adoption process. Adapted from (Hochscheid and Halin 2018), (Rogers 2003).

It has been noted that SME often miss a strategic vision for implementation (Machado et al. 2016; Winch and McDonald 1999).

The purpose of our work is therefore to **build a better understanding of the implementation of BIM in architecture firms** (AF), and to **develop a structured method to support them in BIM implementation**. This method and good practices will be based on organizations' characteristics, strategic issues and perspectives.

In a first place, we will position the implementation step on the complete adoption process. The important theoretical steps that have been identified in the literature to successfully implement BIM are then presented **(part 1)**. In a second part, we present the research methodology used to confront this theoretical method with AF who implement BIM, namely: interview, case studies and action research **(part 2)**. In a third part, we present interviews made with architects in different situations toward BIM implementation: their testimony allows us to identify specific situations, problems and possible solutions for implementation **(part 3)** In a fourth part, we present experiments conducted with AF implementing BIM **(part 4)**. In the discussion, we present the cross analysis of interviews and cases that allow us to make inferences and construct hypotheses **(part 5)**.

IMPLEMENTATION METHODS

Rare research has been conducted to monitor the practical and strategic implementation of BIM in firms. We present here some of them and show how it helps us to construct the method we experiment in the next parts.

Research made on implementation take the form of implementation roadmaps, guides, strategies and methods. To clarify our position, we position our intervention on implementation on the BIM adoption process (fig.1). The implementation support methods we studied **begin after the Decision of Adoption** (DoA) is made by the top management of the firm, and **continue a bit in the confirmation phase**, to limit the risks of rejection after implementation. After than, the firm gradually appropriates and develops its new practices by its own.

Research selected and compared in fig. 2 have different context :

- (Arayici et al. 2011) experimented very early BIM implementation in architecture practice by following four main stages, with action research. But this work only concerned one large firm, JMA architects.
- The research conducted by (Machado et al. 2016) concerned a BIM implementation approach in five steps, in one company.
- Our research team proposed a first version of a method (Hochscheid et al. 2016) (Case 2 in the case study section), developed with a very small architecture firm. This method was completed and consolidated by (Mertes 2017) (Case 3), with a medium firm.

These methods can be divided into four main steps: context study, planning, execution, transfer (fig. 2). These steps, that constitute a draft of BIM implementation method, are presented in the following subsections.

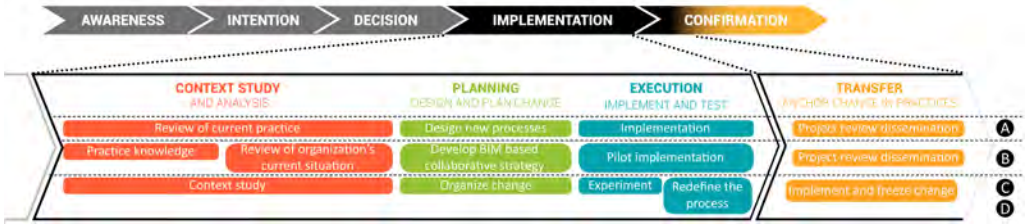


Figure 2
Comparison of four BIM implementation methods (A: (Arayici et al. 2011a; Arayici et al 2011b) , B : (Machado et al. 2016) , C : (Hochscheid et al. 2016) , D : (Mertes 2017)).

Context study

This step consists in observing and analyzing current practices in the organization, in order to provide a personalized implementation strategy and training. Information collected is useful to check the feasibility of change, to identify potential enterprise strengths, process weaknesses and risks for implementation. Information can be charted to make it intelligible and usable of next steps: this is called enterprise/organization modeling. Useful information for studying AF's practice to implement BIM remains to be defined and is an interesting research theme.

Planning

This is the phase during which we set goals and milestones for change. Strategic repositioning of the enterprise with regard to change, evolution of business processes (design the "to-be" process) and possibilities offered by technology are discussed finding a coherent plan of action. In this part, it is important to prioritize and schedule them on a calendar, with regular deliverable deadlines and training times.

Execution

Deal with the objectives following the pre-established calendar by testing different solutions to find the more adapted one. At different points in time during this step, solutions are proposed, revised and finally validated by people concerned by the solution (or a representative of them).

Transfer

This last step corresponds to the appropriation of BIM in the enterprise. This is the moment when processes developed with a "sandbox pilot project" are implemented on an ongoing project. At this stage, the company must have the minimum skills to set up and push the implemented processes forward.

Conditions for the use of this four-step method is not precisely defined yet (who will use it, when, and how). We try to determine what an architecture firm needs to implement BIM correctly, by working with firms, using different methodologies presented in the following part.

RESEARCH APPROACHES

We use a theoretical framework, gather experiences from practitioners (interviews/questionnaires), and experiment BIM implementation with architects to develop the BIM implementation method and roadmap.

Interviews are a good way to get feedback on how the implementation is generally done. This makes it possible to **identify difficulties encountered by the companies**, and to **elaborate hypotheses on the possible factors of failure / success of BIM implementation**. It is also important to **test the method** in a real situation, with professionals ,to get returns and gradually improve it.

But whether surveys, interviews and on-site observation are well anchored in research practices (and can be considered as traditional research approaches), **intervening in the implementation process as a researcher raises several questions** (limits of the intervention, type of intervention, how to exploit results)(Forgues and Lapalme 2017). It is therefore important to clearly define the research framework.

With **traditional research approaches**, the researcher **doesn't (or tries to not) affect the purpose of the study and the results**. **Action research** (AR) is "where the researcher reviews the existing situation (problem domain), identifies the problem(s), **gets involved in introducing some changes** to improve the situation, evaluates the effect of those changes, and reflects on the process and the outcome to generate new knowledge" (Azhar et al. 2009). AR is different from consulting. Researchers and consultants don't have the same approaches, motivation, commitment, foundation for recommendations and essence of organizational understanding (Azhar et al. 2009). The researcher is basically motivated by scientific purposes (not by commercial benefits), and is committed to both client and scientific community (Azhar et al. 2009), which is not the case of the consultant.

In the following section, we present interviews, case studies and action research we conducted.

INTERVIEWS

We conducted interviews with architects, representing 13 architecture firms (AFs). The objective was to identify implementation situations and approach the complexity of BIM implementation in AFs. Out of the 13 firms concerned :

1. **two** have integrated BIM processes **(situation 1)**
2. **three** work mainly in 2D, with occasional 3D and don't want to change their processes **(situation 2)**
3. **two** work in2D/basic 3D and would like to implement BIM **(situation 3)**
4. **six** have several processes coexisting within the company (2D/basis 3D on some projects and BIM on others) for different reasons **(situation 4)**

This panel of 13 firms is not representative of the current situation in France, but proportion of firms in **situation 4** was surprising to us.

In the following sections, we will not discuss **situation 2**, because our objective is not to figure out how to convince firms to use BIM, but to accompany those who so wish. We will not go into much detail about each of these companies to preserve their anonymity, in view of the nature of the information we have been given.

Situation 1: Firms who regularly use BIM on a large part of their projects

These companies (in our panel) are mainly composed of young people who have been trained in these processes and tools at school. In the firms concerned, mastery of these tools is a hiring criterion and managers have developed a strategic vision of their enterprise.

Situation 3: Firms who work with 2D and basic 3D and would like to implement BIM.

Many architects have mentioned the difficulty of standing back from their practice: *"It is true that we are poorly organized, we should have standardized models, we're starting to miss it. It's hard to take the time to review the way we work"* (architect 1). They sometimes evoke the difficulty of implementing it: *"Today, using these tools and construct new processes is important, but I don't see how I can take that step in my firm"* (architect 2).

Situation 4: Firms who already partly implemented BIM

This situation is often synonymous with multiplicity of software in the firm. In the case of a SME, it is economically difficult to maintain, that's why architects sometimes opt for the introduction of unofficial software. Reasons that led to this situation are diverse:

- Implementation has begun
- It is a horizontal-hierarchy firm which makes it possible to choose a technology by personal preference. There is no overall strategy and no pooling of processes.
- The projects in the company are varied and require very different processes

Rarely mentioned in the BIM-specific and change management literatures, these identified circumstances are interesting to note though : the concerned firms may encounter specific implementation problems that need to be studied.

This situation can be brought by **the arrival of a new employee or a new project**. In several firms of our panel, newcomers have brought their workstations with software hitherto unused in the company. These people are likely to be at the origin of a desire for change in the company: *"he showed us that what we thought was not feasible in BIM was in fact possible"* indicates the manager of a business in this case (architect 3). This is an autonomous strategy process, made possible when the company maintains a bottom-up driven strategic renewal (Burgelman 2002).

A **flat hierarchy organization** in AFs makes it sometimes possible to choose a technology by personal preference. *"I and my collaborator work on two different tools because neither of us wants to change it, it suits us like that. If a project arrives for which BIM must be used, she will be working on it."* (architect 4). These firms are a breeding ground for diversity of practices, but if flat hierarchy facilitates internal collaboration and information sharing (Laforet 2013), it also unfortunately leads to interoperability problems in this case within the firm itself.

One architect we met indicated with tried to implement Revit, but **implementation failed**: *"The training was a failure, it was too short. For a training course to work, you need to know exactly who you are talking to in order to propose an appropriate solution, it wasn't the case for us and we are now trying to identify our needs"* (architect 5). The small company has made a substantial investment in training and software. Today, everything is available in the company, but are little used. *"We were not informed of the impact the transition would have on the agency, it was hard. It cost us a fortune, and it made a big hole in our productivity. And there was a missing complement to the training: setting up a template so that we could really be efficient. The transition must be made with serious support"* (architect 5). They gradually try to implement these elements internally, but barely find good practices (adapted to their needs).

These interviews allowed us to identify four different situations of AF with regard to BIM implementation. Situation 4, which we thought was marginal because very little addressed in the literature, seems, in fact, very common.

CASE STUDIES AND ACTION RESEARCH

In this section, we present four experiments conducted within AF implementing BIM (maturity levels 1 and 2, according to (Succar 2009)). The difference with other researches already made on this subject is that we worked with **several small firms**, in several situations. The majority of the cases presented concern ArchiCAD, because it is the most widespread BIM software solution today in AFs. Cases 1, 2, and 3 concern firms in **situation 3** (see the interview section). Case 4 (in progress) is in **situation 4**.

Each of the following cases was the subject of an internship and master's thesis of a master 2 student in architecture. Internships last 6 months during which students work part-time for an effective duration of 2.5 months. Students who participated have all received in-depth training on digital tools, project management and BIM concepts and applications . The position of the student and its link with the research laboratory was used as a variable in the experiments. Each experiment followed the four steps seen before: **1-context study; 2-planning; 3-execution; 4-transfer**.

Case 1

This case (Sauvage 2017) concerns a firm composed of two architects who work mainly on public contracts as schools and museums. The objective of the operation was to move the firm (working on AutoCAD) to a BIM level 1 as a first step (ArchiCAD) : architects would like to have access to competitions that require now BIM.

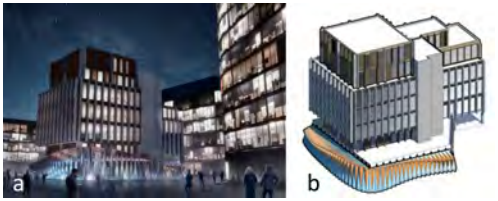
The student had no contact with us during his internship and implemented a change management

plan on his own. In addition to the objectives of his internship, he participated in the firm's production as an architect.

Context Study. First, he observed how the company operates. He produced an "as-is" BPMN representation and a network diagram.

Planning. Over the duration of his internship, he planned the implementation (training times included), taking into account the firm's provisional schedule. The firm acquired the software.

Execution. The student worked on two current projects of the firm, with several softwares (fig. 3). Architects of the firm were very busy, it wasn't possible to work on already completed projects first. The student gradually integrated graphic codes of the firms in an ArchiCAD type file. He regularly conducted himself small training sessions for the architects.



Transfer. In order to allow architects to use ArchiCAD after his departure, the student created help files and memos, specific to the needs of the firm and the sample file he created.

The architects were sensitive to the presentation of the possibilities offered by the tools. Despite the planning, training times were not kept. Reason given was the architects' overload of work. But the fact that the trainee organized these training certainly prompted the architects to give these times a lower priority than if they were economically engaged with an external actor for training. The student worked almost alone on the new projects on ArchiCAD. After the end of his internship, the architects did not start a new project this new tool, because they considered the operation too risky and had difficulties to free time to implement it.

Case 2

This case (Hochscheid et al. 2016) concerns a firm of two associate architects that had just moved to ArchiCAD (a few months before the experiment). This firm works mainly on individual wood-frame home projects, closely and regularly with a carpentry company. Seduced by the possibilities of BIM level 1, the architects wanted to experiment BIM level 2 by exchanging IFC files with carpenters who work with cadwork. BIM level 1 was not fully integrated into practices, they were completing projects on AutoCAD and hadn't yet started projects on ArchiCAD.

Two students participated in this experiment: one was within the architecture firm (Ribereau-Gayon 2015), and the other within the research center (Hochscheid 2015). Three organizations collaborated: the architecture firm, the carpentry firm (that allowed us to observe its practices in detail) and the research center.

Context Study. The student within the laboratory has created a framework of elements to observe within the two firms as the immersion student began to participate in the production of the architecture firm.

Planning. The students modeled the "as-is" and the "to-be" processes with BPMN (Business Process Model and Notation), according to the demand and needs of the architects and carpenters.

Execution. The main work consisted in carrying out a number of import and export tests in IFC between the two software to achieve the "to-be" process (Hochscheid et al. 2016). The student immersed in the architecture firm modeled on ArchiCAD the "sandbox project" (previously done on AutoCAD) to test the import exports in real - but secured - conditions.

Transfer. The operation resulted in an IFC import and export profile, accompanied by a process and advice of good practices, transmitted to both firms.

The presence of a student in the laboratory allowed time to conceptualize and develop an implementation method (Hochscheidet al. 2016). The stu-

Figure 3
Renreded pictuces of one demonstration project. Software tested : ArchiCAD, Revit, Grasshopper, blender and Artlantis. (Sauvage 2017)

Figure 4
Conduct of the experiment for case 3: main milestones and important events.

dent who worked in the firm was hired, to retain acquired skills within the company. A second young architect competent on these issues have been hired since.

The managers are now less dedicated to graphic production: they concentrate on administrative tasks. The firm still regularly collaborates with partners by sharing digital mock-ups. BIM level 2 has become part of their practice.

Case 3

This case (Mertes 2017) concerns a firm of about fifteen architects that has a diversified production, as much by the size of its projects as by their program (individual houses, public markets, interior arrangement).

The objective of the operation was to implement and make the firm operational on BIM level 1 (with ArchiCAD), by training, implementation of new working methods and the delivery of an operational ArchiCAD startup file adapted to their practice.

The student was this time integrated to the research center, and visited the AF regularly. Figure 4 is a summary of the conduct of the experiment, with the four main milestones and important events.

Context Study. The ArchiCAD trainer carried out an in-depth audit of the company, in particular by conducting interviews with various architects of the firm; we completed this information with our observations.

We identified the most suitable project type to implement BIM first, and individuals within the company who would be part of the transition group.

Planning. Interior design projects were chosen to test BIM level 1 because they are of short duration and represent a large part of the AF's turnover (duration of a project has been identified as a factor of reluctance to change (Lines et al. 2015)).

The AF has a well-defined graphic charter and a library of objects that has to be respected. It was therefore necessary to identify elements to convert in ArchiCAD format to make it possible for the AF to be operational on ArchiCAD. These elements were then prioritized and organized on a calendar (fig. 4).

The *transition group* was composed of researchers and two architects from the firm. The first one is high up in the hierarchy, has the confidence of the top management, is motivated by the transition and is in charge of the technique in the agency. The second one is a young architect, who masters ArchiCAD and works on the interior design projects.

Involving internal people from the firm ensured the coherence of the change project and made it possible the transfer of technology/competencies after the trainee leaves (unlike case 1).

Execution. The trainee worked on the transcription of this library and graphic charter on the new tool . During this phase, the transition group has been consulted very regularly (fig. 4, 5).

Figure 5
Process of development improvement and validation of solutions during the execution phase

As the firm has always worked on AutoCAD with strict and well-defined methods, we have been asked to provide the ability to view the project on ArchiCAD as it was previously viewed on AutoCAD, to facilitate project checking. The firm's training took place at the end of the trainee's internship. The developed library and starting file were used as a basis for the training of the firm to facilitate its integration.

Transfer. Members of the transition group had a more in-depth training to allow them to evolve these documents after the trainee leaves. Training sessions continued after the trainee's departure, and the members of the transition group were trained to make files and processes evolve.

The first projects carried out on ArchiCAD (interior design projects) have shown the effectiveness of the new process, which has been adopted. Nearly one year after the first projects carried out in this way, the agency began to launch other types of projects on ArchiCAD. The trainee left the firm and works now as a BIM coordinator in quite a larger firm.

Case 4 : in progress

We are currently (March 2018 - August 2018) working with a six-person firm that moves from Vectorworks to ArchiCAD (BIM level 1) and wants to experiment exchanges with its partners (BIM level 2). Two people within the firm have already been working with ArchiCAD for a year and already experimented BIM level 2 in this firm (they are in **situation 4**).

The objective of this ongoing transition and to generalize BIM level 1 with ArchiCAD in the firm, and exploit BIM level 2. The trainee is this time within the firm, and works closely with the research center.

However, it is too early to develop this case, which is still in progress.

DISCUSSION

Situations presented are diverse and offer us avenues for evolving the proposed method. During the interviews, we highlighted a situation that seems to be a common occurrence: companies who half-implemented BIM (situation 4). Experiments show that BIM (levels 1 and 2) is of interest for small businesses, and for different types of projects (including small projects, such as individual houses (CASE2)). The small size of the projects is even an advantage for the implementation (CASE 3).

The implementation should be preceded by an audit and study of the company's practices to assess needs and risks that the company faces for the transition (CASE 2, 3 and architect 5).

Here are elements we retain for the construction of our method and good implementation practices from interviews with architects (named architect x) and action research/case studies (named CASE x)

Time management. It is important to set up personalized tools (start-up files, interface settings, company cartridges, templates, development of internal processes) so that the AF can start working on the new tool and limit the loss of productivity (architect 5). However, employees of AF often do not have the skills or time to develop these customized tools (architect 1, CASE 3). When the trainees were internal to the company, their time tended to be absorbed by the firms' production (CASE1, CASE2). This situation is currently happening in CASE 4: the schedule of the firm's migration has been deviated because the intern was asked to participate in the production of the firm which experienced a one-off peak of activity. For this reason, the person in charge of the transition should perhaps not be internal to the firm.

Change agent(s). When a new person, external to the firm, is dedicated to this migration, his departure is difficult to manage (CASE 1) and can jeopardize the change operation. Measures must be taken to transfer skills, start-up files, interface settings and the ability to modify them. Two solutions are envisaged: (a) hiring the person to keep the skills in-house (CASE 2), (b) work with a transition group composed of people who work in the firm and receive an in-depth training (CASE 2).

Habits. The loss of reference points on new tools can be consequent. The weight of habit is an important factor of failure of the implementation (lock-in). People are tempted to go back to previous practices,

which allows to recover their habits and avoid the loss of time caused by learning a new tool. To limit this effect, it was asked to us (in CASE 3) to produce a visualization on ArchiCAD close to the usual visualization that the architects parametrized for AutoCAD. This practice is not necessarily optimal: it can reduce resistance to change at the beginning but it can also slow down the complete appropriation of the new tool.

Young architects and education. Education and training of the future generation of architects play a major role in the transition because their integration into companies is often the main change vector (architect 3, CASE 2, 4). The migration of a firm to a new tool is often accompanied by a withdrawal of the managers with graphic production and modeling, which is transferred to young architects (CASE 1, 2, 3) (Moreover, in CASE 4, the managers spontaneously mentioned their fear of withdrawing from production, because they are currently actively participating in it).

Secure tests. It is interesting to work first on a "sandbox pilot project" (an already completed project) to test the new process and anticipate problems (CASE 2, CASE 3). This seems to be quite efficient to anticipate problems but is time consuming. Projects we chose for production testing are generally short-term projects because it allows rapid feedback on the implementation (CASE3). Migration has only been made on new projects (not current project began with previous processes) to limit risks and time loss.

Training. The more training and effective implementation are distant in time, the more difficult it is for architects to begin to appropriate the new processes. Training should therefore be judiciously planned. The training spread over several months reduces return to previous practices (CASE 3): it is a long-term follow-up. However, this requires a significant financial investment on the part of firms.

Firm's culture. BIM implementation seems to be easier for firms who integrated resources pooling, process standardization and pyramidal hierarchy (CASE 3). Note that this functioning is rare in French AFs who often work in traditional way (architect 1).

Project teams and external partners. Often work with the same partners facilitates implementation of BIM level 2, because the processes developed once with the partners can be reused and made profitable. The ephemeral nature of project groups in the construction sector has also often been cited as one of the reasons for the slow diffusion of innovations within the sector.

Enterprise modelling. BPMN is interesting to represent processes in AFs in the case of BIM implementation. Even students disconnected from the research center (CASE 1) went to this type of representation to analyze the processes they were facing. In all cases presented (CASE 4 included), as-is (and sometimes to-be) BPMN process was drawn.

CONCLUSION

For most architecture firms in France (most of which work with AutoCAD + SketchUp), implementing BIM means, first of all, changing their main work and production tool. So this is a significant and deep organizational change. BIM training offers are today often focused solely on the use of tools, it is difficult to find support on the evolution of business processes and strategies.

In the cases we met (which may not be representative), the real upheaval in practices therefore lies in implementing level 1.

The experiments we have conducted (notably in observation and action research) with architecture firms allow us to better understand the difficulties related to the implementation of BIM in architecture firms.

We try to define the "good practices" of implementation But there's no indication that architecture firms would have the desire or the financial means to call upon them. One of the AF managers of a firm we followed confessed that he would never have financed such the follow-up we offered by action research, although he recognizes its benefit.

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