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Abstract: The paper studies the management needs for innovative design in a factory. An experiment launched in the Airbus's factory at Saint-Nazaire shows that an innovative type of design can exist in a factory. It offers long-term solutions for manufacturing and redefines the performance at the shop floor level. The following article questions the management needs for this design. The paper is based on a qualitative and quantitative analysis of 30 cases of design approaches, innovative or more conservative one. The article shows that the composition of the team, the role of the leader and the available means to drive the approach are critical in the management, and differ from the management generally applied in an industrial context (continuous improvement or industry 4.0). It gives keys to the practitioner to consider the management practices adapted to an innovation approach at the shop floor level.

INTRODUCTION

It was shown that in a factory two regimes of design can co-exist (Harlé et al. (2019)). They constitute two different approaches to solve the problems at the shop floor level. The first one corresponds to a problem solving approach, commonly used for the manufacturing processes through, for example, the implementation of the tools derived from the lean management and the continuous improvement, or through participative system aiming at collecting the employees' ideas and gaining from there creativity. Another type of design, more innovative, and less expected in a factory, was observed in the Airbus's factory in Saint-Nazaire (France). One of the interests of this design relies in the success reached and the performance generated. The two types of design were concomitant in the factory. Whereas the classical problem solving remained used and valid for numerous problems that had to be solved at the shop floor, the innovative design appeared to be highly interesting and efficient when the former classical solutions failed during the implementation. However, this design seems to be organized and managed in a conscious and scrupulous way. It results from practices and steps carefully thought and implemented.

The aim of this paper is to address the question of the management needs for this regime of design. Indeed the observation pointed out a management adapted for the implementation of this second approach to solve the problems. The management observed was different from the management observed in a traditional manufacturing system, inherited from the evolution of the industrial management during the XXth century, implying lean management, continuous improvement… One can think that, because of its innovative side, this management looks like a step towards the management of a factory 4.0, triggered by the Internet of Things (IoT), the big data, the automation and the digitalisation of the factory. However, the literature and the observation at the Airbus' factory are not in accordance with this management paradigm.

The paper is based on a longitudinal study at the Airbus Saint-Nazaire's factory. 30 cases of design approaches, from classical problem solving to a more innovative design approach, were selected for the analysis. The main managerial characteristics highlighted by the experiment were the appropriate choice of the team, the specific role of the leader, and the avoidable means to drive the process. This paper intends to clarify those determinants. It enlightens the specificity of the management needs for the innovative design at the shop floor level.

The particularity of the paper lies in its manufacturing context. This regime of design, expanding the rules of the factory, involving the employees at the shop-floor level, and enabling long-term results associated with new criteria of performance, has not been studied in details yet.

Finally, the article gives a new comprehension of innovation and change management practices in a factory. It indicates directions for the practitioner. In a broader perspective, it contributes to explore what the future of the factory could be.

1 LITERATURE REVIEW

There is a stream in the literature that studies the link between the human resource management and the performance (Jayaram Droge, and Vickery (1999), Santos (2000), Ahmad and Schroeder (2003)). The authors look for a relation between management practices and some dimensions of the performance. However, it could be interesting to draw a broader panorama of the management needs according to the industrial context. We can roughly distinguish between, on the one hand, the "classical" manufacturing system, inherited from the evolution of the industrial management during the XXth century, implying lean management, continuous improvement, and on the other hand, the "industry 4.0" which is triggered by the automation, the digitalisation of the factory, and the implementation of the Cyber Physical Systems (CPS). Hence, two wide models of management are described in the literature. They are consistent with the type of factory in which they are applied.

Thus the following literature review shows the management needs that arise from each type of manufacturing system.

1.1 The management adapted to the continuous improvement

During the XXth century, the management is characterized by the implementation continuous improvement on the work, automated or not. The continuous improvement can be defined as 'the planned, organised and systematic process of ongoing, incremental and company-wide change of existing practices aimed at improving company performance' (Boer et al. (2000)). It takes its roots in the Toyota's movement and on the quality movement launched by Shewart in the 1920 with the Plan Do Act check cycle (Zangwill and Kantor (1998)). The operators have to face manufacturing problems and to be able to continuously increase the performance through quality, cost, productivity etc. To promote and amplify innovation, the need for a participative management was claimed (Delbridge, Lowe and Oliver (2000), Lantz, Hansen, and Antoni (2015)). It can be autonomous teams, suggestion systems to collect employees' ideas at the shop floor (Vanharanta (2018)), or the encouragement of *bricolage* (Cunha (2005)).

Team: To manage this continuous improvement, the need for teamworking is emphasized (Delbridge, Lowe and Oliver (2000)). The operators need to be skilled, in order to be more autonomous through organized groups like quality circles or self managed teams. *For* Lin, Tung-Ching, et al. (2015) the complementarity of the expertise in the team *can be viewed as an aggregation of various heterogeneous resources and competence which members require of each other while performing tasks.* It is one of the conditions for the problem solving approach to be efficient. The composition of the teams including varied and complementary backgrounds and experiences not only guarantees diverse viewpoints but also bring different sets of skills, perspectives, and knowledge to the project (Singh, Gupta (2014)) highlights the necessity for the fields of expertise to be integrated. "*Expertise is integrated when at least one piece of knowledge from one individual is used together with expertise from another team member to accomplish a project task*" (Manohar Singh, Gupta (2014)). Understood in that way, the fields of expertise of the team members define the frontiers for the labour division in a problem of improvement. Each expert is responsible for his field of specialization.

Leadership: Then, the leader has to organize the work of the group. With more or less autonomous according to the leadership style, he plans, controls and inspires a collective and emulation feeling in the team etc. (Kathuria, Partovi, and Greenhaus (2010)) states several components of the leadership : *networking, team building, supporting, mentoring, inspiring, recognizing, rewarding, consulting, delegating, planning, clarifying, problem solving, monitoring, and informing.* Finally, the leader gives the framework of the practice, gives the timing of the project, and enables that the system better works. He guarantees the keeping of the rules.

Available Means: Finally, the means to help the operators to solve the problem are already in the factory. The literature does not stress particular external means (actors, places, knowledge) to solve the problems in a factory.

1.2 The management adapted to the industry 4.0

The "industry 4.0", "future industry", "smart manufacturing" are terms that suppose the base of the process on an increasing automation and digitalisation. In this trend, the Cyber Physical System (CPS) consist in the connection of sensors from machines and devices, integrated and connected to digital communication networks (Gehrke, Lars, et al. (2015)). A large amount of data and indicators result from this interconnection and are transferred to the operators. The risk lies in feeling in a complex system, under a too wide information flow, comprising undecidable pieces of information (Kadiri et al. (2016)). **Team:** The team is viewed as an aggregation of experts. The stress is put on the skills of the workers. The tasks assigned to them change, and consequently, their skills also evolve (Berger (2014)); "*Information and data will be the basic elements the skilled labourer works with, using all kinds of new devices and assistance systems* » Then, the workers need to be able to work with data, and to take the final decision (Gehrke et al.(2015)) Consequently, the technical skills and expertise will be more oriented towards statistics, programming, coding, IT security… (Word Economic Forum (2016)). Moreover, the operators at the shop floor need to be expert of the process, but also of the machine that makes the process automated. Thus, in the 4.0 manufacturing system, monotonous and routine tasks will be automatized, letting the worker for non autonomous tasks, such as the maintenance, which becomes a very important task for the employee. (Sipsas et al. (2016)). More than the technical skills, the methodological skills are needed for problem solving, and decision making (Davies, Fidler, Gorbis (2011)).

Creativity is needed to improve the processes and the products. Furthermore the work in a factory 4.0 can be seen as the complementary of the machine, with the operators making profit of their experience to improve the processes through improvisation (Pfeiffer and Suphan (2015)). This article insists on the intuition and the human feelings behind the control of the automated machine by the operators. This ability is developed by experience: "theoretical knowledge and routine are used in the standardized processes characteristic of the industry 4.0, but there is also the experience enabling intuition and feeling, and to cope with the unpredictability of the processes" (Pfeiffer and Suphan (2015)).

Leader: The leader needs to implement the « context awareness », which consists in organizing the system in order to become comprehensive and adapted to the expertise of the operators concerned (in other words, organizing the information flow (Gehrke et al.(2015)). The leader makes possible the decision to be taken, promoting the sense making (« the ability to determine the deeper meaning or significance of what is being expressed » (Davies, Fidler, Gorbis (2011)).

Available means: the literature, as explained in the paragraph "team", emphasizes the potential gap of knowledge on the data processes. However, not other means external are stressed to bring into the factory to solve the problems.

1.3 The management adapted to the innovative design in factory

Harlé et al (2019) stresses the existence of another type of design approach in the factory. Its main characteristics are, for example, the specific approach and measure of the problem, the exploratory way of looking for a solution, the determination of the final solution. The article shows that the solution designed in this regime is often implemented on a longer term than the solutions found with a usual problem solving approach. However, the management in factory for this type of design has not been studied yet. Lakemond and Holmberg (2018) suggests that the complexity of the future manufacturing systems requires a "*new understanding of rationality",* such that the intelligence of the system and the human cognitive understanding interplay. Moreover, it claims for a research program on the factory about the finding of the non-existent alternatives in a safe and reliable way. In this line, (Davies, Fidler, and Gorbis (2011)) indicates that the future work skills has to include "novel and adaptive thinking: proficiency at thinking and coming up with solutions and responses beyond that which is wrote or rule-based ». The stake is to enable the team to build on a solution beyond a choice between already-known alternatives (Lu and Conger (2007)).

Team: The management needs for this type of design can be derived from the literature on the innovative design in a broader field of application than the factory. For example, (Rittel (1977)) mentions the need for a composition of the team where members are experts but only partially: the expertise and the ignorance is distributed over all participants. The leader should be the one who implement the design approach at the shop floor level. In particular, he should motivate the approach in several and redundant steps. Dorst (2006) suggests that first the leader should care about the to measure the problem in a relevant way. Then he should drive a process of "co-evolution" between the problem and the solution, by exploring, testing, observing the results of the test and redefine the problem and the solution.

Available means: the literature gives several keys to foster the creativity. (Goel (1997)) insists on the role of analogies to solve the problem. Vattam, Helms, and Goel (2010) gives an example of analogy commonly used, the biological one. The management need associated with the search for knowledge is the possibility to enter the factory with new and unexpected knowledge. In the same philosophy, the place attributed for the work could be outside or different from the shop floor (Drake 2000, Moultrie (2007)).

All the management needs for each of the factory type are summed up in the following table.

Table: *Summary of the theoretical management needs for the different types of factory*

	Lean manufacturing Continuous improvement	**Industry 4.0**	**Innovative design in factory**
Composition and perimeter of the team	The team is consistent with the production process. It is composed by experts to make possible a sort of division of labor into the team	The operators are expert of the machines. They solve complex problems and take decisions.	The team is not consistent with the production process. Other external people take part to the debate
Leadership	The leader plans in time and in step, controls the compliance with the rules	The leader verifies the conformity with the rules of the system, and validates the decisions.	The leader enables the exploration process, iterative, with precise and adequate measures. He encourages the alternative solutions. He enables the revision of the rules.
Available means, places, time	Time limited, means already available in the factory	The means are conformed to the system and the rules.	The means (knowledge, places to visit, people to meet), can be outside the factory. A place is devoted in the factory for the meetings.

In conclusion, the literature review gives the characteristics for the management according to the type of factory. The description of the management needs for the "traditional" and the 4.0 industry are known and already applied. However, the management needs corresponding to the third regime is not clearly defined in reality, and there is a lack of empirical proof of existence and of efficiency of these management practices.

2 RESEARCH QUESTIONS AND HYPOTHESES

2.1 Research questions:

The paper aims at answering to the following question:
To what extent the third type of management described in the literature review for the innovative design is empirically verified?
That implies two questions:
QR1- What are the management needs compatible with an innovative design approach at the shop floor?
QR2- To what extent do they differ from the management needs of the other industrial approaches?

2.2 Hypothesis

H1- There is a management adapted for the innovative design in factory;
H2- It differs from, but is not opposed to the classical and industry 4.0 management paradigms.

3 METHODOLOGY AND DATA

In order to answer the research questions and to test the hypotheses a longitudinal study was conducted in the Airbus Saint-Nazaire factory (France) from 2013 to 2018. A long-term collaboration was established between the company and a team of researchers of Mines ParisTech's chair *Design Theory and Methods for Innovation.* The aim of the collaboration was to detect, understand and experiment the design activity for innovation at the manufacturing level, its organization and its management. Moreover, the partnership intended to analyse the accordance between the innovative design practices and the initiatives concerning the industry 4.0.

This article is based on 30 cases study. They were collected by several semi-directive interviews. Then they were coded in function of their management practices, according to 3 dimensions: the team composition, the leader's role, and the available means to solve the problem. They were also categorized in function of their design style: the classical problem solving approach or the innovative design. The coding step was discussed with the practitioner who organized the cases.

The article then takes two emblematic cases study already examined in Harlé et al. (2019) to highlights the managerial side of the cases. Then a quantitative analysis is derived from the data.

4 ANALYSIS

The aim of the analysis is to check if the model written in the literature review for the third regime corresponds to the observations at the Airbus' factory.

4.1 Cases study: two types of management for two approach of design

In this part, the cases study developed in Harlé et al. (2019) are commented from a managerial point of view. The cases were chosen for their adequacy to the typical forms of design that can be found at the shop-floor to solve the problems. Here the composition of the team, the role of the leader and the available means for the team to tackle the question will be pointed out.

4.1.1 Case 1: listing and implementing golden rules to improve quality

The case: The final stage of the manufacturing process is a quality control that gives a grade for each product leaving the factory, according to the quality criteria pre-defined.
The direction of the Airbus Saint-Nazaire's factory decided to increase the general quality of the products at this stage. For that purpose, a workshop was organized. It gathered, during a whole day, all the managers responsible for the successive stages of the production. They were asked to discuss about their way of managing quality in their production workshop. Then, they should debate about their good practices, and should finally set up a list of ten "golden rules". These rules were adopted and implemented by the managers gathered at this one-day workshop. Though, the average quality grade at the final stage did not increase.

Commentary: This case depicts a situation of design in a classical manufacturing environment. From a management point of view, this case is classical of a problem solving approach applied to a quality improvement process. First, the team is consistent with the manufacturing organization. Apart from the leader, it involves the team managers of each manufacturing workshop concerned. At the end of the process, every one is supposed to become "expert" on the question of quality for its part of the manufacturing process, according to a sort of labour division applied on the problem. There is no one external to the team and to the field of "quality in manufacturing" to bring new knowledge on the question. Second, the leader is a manager not directly implied in the manufacturing process. His role consists in giving the framework, formulating the instructions to implement a tool, "the golden rules", that he previously identified as suitable for the problem to solve. He pays attention to the good elaboration of the rules by the group. At the end, the definition of quality is not changed, and the rules on quality are the same. The role of the leader is to improve the action in order to enable a better execution of the rules. For that, he fixed a period of time to solve the problem. In one day, the team gathered and list the ten golden rules. At the end of the say, the leader considered the question as closed.

4.1.2 Case 2: internal notes

The case: When a product or a part of a product is detected as not compliant with the standards given by the engineering office, a process of the non-conformity treatment is implemented. A file is opened, with pictures, dimensions, description of the problem etc. The file is sent to the engineering office, which processes the case through successive steps (for instance, the address to the appropriate engineering team, the proposition of a solution, the calculus of the properties of the new solution, the validation of the solution…). At the end, the solution is executed in the production. Although this process is efficient on a quality point of view, it is very long and suffers of delays due to an accumulation of cases to be treated. A team was gathered to address the problem. The team spent a few meetings to launch analysis to measure the problem and understand it, to elaborate and test a new process. Finally, the process of the non-conformity treatment changed: it became shorter for several redundant cases. They do not need to follow all the steps because they often occur and the operators at the shop-floor level already know the final solution. Consequently, the problem of blockage and delays disappeared.

Commentary: This case is identified as a case of innovative design in factory.
The management of this case differs from the previous case. Concerning the composition of the team, the manager is also an external member of the firm. He participated to the elaboration of the solution as active member of the group, and his external point of view was determining for the process. The other members were employees at the shop floor (between 5 and 10 people). The group knew that the process is not well known. There was no expert of this process relying on internal notes, and the team had to know it better. The leader encouraged the team in a design process where the solution would be thought and improved in an iterative way. First, he considered as partially badly known the problem. He asked for time to follow, in real time, a few internal notes to better understand the process. The group invested several propositions, and the leader insisted on the test, even partial, of the solution. The group not only tested the validity of the propositions, but also observed the effects and took them into account to enrich the solution with the elements discovered. The leader gathered people once a week during five months, encouraging and enabling the comprehension of the rule and the revision of them if necessary.

4.1.3 Conclusion of the cases study

These cases study gives a better comprehension of the theoretical model depicted in the literature review. Exhibiting concrete examples of design approaches to solve the

problems at the shop floor, it shows that different types of management occur. In particular, to drive an innovative design approach, a specific organisation is needed.
Considering the available means, other examples show the possibility to be inspired by practices from other fields. For example, in the cases, interviews with pilots concerning their vision of the security, a visit of a nuclear plant were noticed. A closer dialogue with the suppliers, and with the engineering office was also started.

4.2 Quantitative analysis

This analysis explores the link between the management variables derived from the literature review (the team composition, the role of the leader, and the available means) and the type of design, innovative or not. As explained below (methodology), the coding step was done during 7 semi-directive interviews of two hours with the organizer of these cases.
A test of independence (or Chi-2 test) of 1 degree of freedom at the 5% level is implemented to test the independence of the design type with one of the management variable.

4.2.1 Test of independence between the design and the team composition:

Hypothesis:
H0: The type of design and the team composition are independent;
H1: The type of design and the team composition are not independent.

Results:
The test gives a calculated statistics equal to 8.51, which is higher than the theoretical statistics 7,88. The p-value is equal to 0,004.
Conclusion: H0 is rejected at the 5% level.

4.2.2 Test of independence between the design and the role of the leader:

Hypothesis:
H0: The type of design and the role of the leader are independent;
H1: The type of design and role of the leader are not independent.

Results:
The test gives a calculated statistics equal to 23.14, which is higher than the theoretical statistics 7,88. The p-value is equal to $1.506 .10^{-6}$.
Conclusion: H0 is rejected at the 5% level.

4.2.3 Test of independence between the design and the available means:

Hypothesis:
H0: The type of design and the available means are independent;
H1: The type of design and the available means are not independent.

Results:
The test gives a calculated statistics equal to 9,84, which is higher than the theoretical statistics 7,88. The p-value is equal to 0.001.
Conclusion: H0 is rejected at the 5% level.

4.3 Conclusion of the analysis

The analysis answers to the research questions. It shows that the management needs for the innovative design seem to be specific for this approach. In the cases of classical problem solving, the management, in term of team composition, role of the leader and available means are not the same. This analysis, with the cases study and the tests of independence, reflects the wish for the Airbus' factory to experiment, in a pragmatic and rigorous way, a new and original manner of thinking the innovation at the shop floor, implying the manufacturing operators. It is new, because it does not refer to the classical management paradigm commonly used in the factory. It is also original because the innovation could have been a step towards the main and common characteristics of an industry 4.0. Though the factory tried another type of management. It is compatible with the present one (since the projects are launched in the same period of time). It is also compatible with the 4.0 initiatives that the factory implements. Indeed, some of the cases were about the digitalisation or the automation of the factory.

5 DISCUSSION: THE MANAGEMENT FOR THE INNOVATIVE DESIGN IN FACTORY

5.1 The innovative design in factory is managed along a controlled process: it does not come from intuition or improvisation.

The analysis shows that the management for the innovative design in factory is very different from the classical management for problem solving. It relies on the participation of the shop floor to design processes. However, the traditional participation movement gathers ideas of people *via* suggestion systems or context to trigger creativity and innovation; the industry 4.0 is supposed to support the improvisation and the human reactions of the employees facing the machine (Pfeiffer and Suphan (2015)). Here, the innovative design process in factory is rigorously driven and controlled. The meetings were used to measure the problem and identify and gather the knowledge on the problem, then experiment solutions or partial solutions and then control its effects afterward and improve it. Then, the team leaders detain a significant role of management of this process.

A corollary of this property is the possibility to break the rules in a controlled, pragmatic and scientific manner. Indeed, the leader of the classical management system, as well as the one of the industry 4.0, gives the instructions to be conformed to the factory prescribed framework. Here, the prescription becomes open, since what roots the rules is known and taken into account into the new process.

5.2 The innovative design process in factory is collectively managed.

On this point, there is an opposition with the classical and 4.0 management. In the classical management, the dichotomy between the leader and the participants holds. The leader has the role of fixing the plan and controlling the compliance with the rules of the factory. The members of the group act in function of their field of specialisation. In the industry 4.0, the team working is not widely emphasized in the literature. The leader has a technical role to spread information at the right place and at the right time. He also validates the decisions. The operators have to face complex problems and to solve them thanks to their high skills in automation and digitization. On the contrary, the innovative cases were collectively built; the solution was not based on the expertise of one person in the group, but on the collective comprehension of the problem and of the knowledge to acquire in order to tackle the question.

The collective approach leads to recognize as a skill the participation to a design process for the leader of the team, but also for the participants. Implementing an innovative design in a factory remains a collective learning, to conceptualize, to explore and to experiment.

5.3 The management for an innovative design in factory redefines the frontier between engineering design and manufacturing.

In the classical management, the problem solving approach is organised to answer the question by the fastest and most secured way, with a scarce of resources. The idea is to capture the design outside the manufacturing for a better division of the tasks and a better efficiency in the industrialisation process. The industry 4.0 keeps this approach, designing ex-ante all the automated system. However, if the manufacturing management enables a control of the design approach, and if the factory is considered as a place of collective learning toward design, the frontier between the manufacturing on the one hand and the engineering design and engineering manufacturing on the other hand changes. This point should be investigated in further research works.

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