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Development of a new framework for implementing industry 4.0 in companies

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Abstract

Globalization introduces incertitude for the future of companies. They could disappear more quickly for economic reasons or increase exponentially their position on the market (profit, turnover). Indeed, Logistics and task force costs are important for implementing a new factory in a country. Then, the concurrence is unequal for European and developed countries. Industry of the future appears in this context as a new method based on new technologies deployment (and organization) for improving company performance.

Many concepts are being developed in the frame of "factory of the future". Most of them, insist only on new technology integration everywhere in manufacturing processes or on company supply chains. Thus, industrial problems could be solved very quickly by using machines, robots, cobots, RFID, but also internet of thing (IoT), decision aided tools, etc. Some of them integrate social aspects in their framework. But, none of them are based on sustainability in future changes. The main objective of this new framework is to put this sustainability as the kernel of future company evolutions in the frame of 'Industry 4.0'.

This paper will focus on concepts of this new factory framework for defining changes and steps in the frame of factory of the future. Based on sustainability (social, societal and environmental dimensions), and in addition to new technologies and organization, flexibility in company position would be added as one of main development factors.

After presenting concepts and formalisms of this new framework and how they could be used on a company, a detailed illustration example will be shown for validating concepts elaborated. In this paper, artificial intelligence (machine learning, expert systems, multi-agent systems) will also be used for defining the structure of a decision aided tool in order to optimize company dispatching flows.

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1. Introduction

The impact of emerging countries on the new market organization is important. Due to low cost of working force, and production processes, companies of these countries have an advantage in the globalization organization. Developed countries companies have to invest in innovation and high-performance processes for being competitive. Indeed, this is not a problem for large companies, because they are generally implied in other world countries and have adopted concepts, methods and tools of industry 4.0. Then, the use of advanced technologies such as mobile robotics, cobots, robots, RFID, etc. for improving their performance is current. The integration of information systems, IoT, big data, decision aided tools, blockchain, etc. has no secret for them.

Concepts associated to flexibility, market evolution, new technologies and organizations are mainly used by theses large companies. But, the implementation of industry 4.0 concepts for aiding SMEs in globalization problems solving has no success in Europe and specifically in France. Reasons are numerous, but never well-presented and solutions for changing this bad perspective are not well-defined.

This paper presents a new framework being developed in Icam (engineering high school) for industry 4.0 implementation in SMEs. The implementation brakes are clearly shown and solutions for changing these SMEs by implementing industry 4.0 concepts are exposed. The framework being elaborated integrates sustainability as the kernel of industry 4.0 implementation and organizes the process of implementation around this main dimension. As sustainability criteria, social, societal and environmental aspects have to be considered.

After presenting this framework and associated concepts, the architecture of a decision aided tool being developed for supporting the SME industry 4.0 implementation process will be shown.

Then an illustration will be used for exposing the global utilization of the framework and how the tool being developed could contribute to increase the number of SMEs deploying industry 4.0 concepts and to improve each SME global performance.

2. Literature review

The main objective of industry 4.0 and logistics 4.0 is to modernize company logistics and industrial tools for increasing their performance and being adapted to future evolutions. Indeed, company models are being transformed and it would be benefit for companies to anticipate this transformation. The introduction of digitalization, and new technologies [1], [2], [3] is important but changes according to business, organization, design or sales have to be taken into account for increasing company performance. Thus, a detailed study of literature allows to:

- Find orientations on industry 4.0 concepts and logistics 4.0 and to discuss about their pertinence
- Determine brakes for industry 4.0 and logistics 4.0 concepts implementation in SMEs and define levers for accelerating their implementation
- Elaborate reasoning necessary for elaboration a problem-solving method in order to support changes in the frame of industry 4.0 and logistics 4.0
- Develop a decision aided tool for aiding SMEs in the implementation of industry 4.0 and logistics 4.0 concepts

2.1. Industry 4.0 and logistics 4.0

Since 2011 and the first publication on industry 4.0, many researchers have worked on this topic and concepts defined could be summarized by different frameworks. But most of them are focused on new technologies as the kernel of industry 4.0. For instance, in [4], the paradigm of industry 4.0 is outlined around three dimensions:

- The horizontal integration across the value creation network,

- The end-to-end engineering across the product life cycle,
- And the vertical integration combined with networked manufacturing systems

Then Micro and macro perspectives presented are based on organizational and technological aspects. Thus, advantages and objectives of industry 4.0 are focused on digitalization, new technologies as presented in [5]: Cyber-physical systems, big data, real time data management, ICT, Internet of Things, Distributed and decentralized control, RFID, etc. The concept of smart factory, and smart manufacturing is developed in detail in this context [6]. Economic aspects are also developed in [7] for presenting processes used for improving company global performance in terms of cost reduction and turnover increasing.

2.2. Brakes of industry 4.0 implementation in SMEs

SMEs are not ready for adopting industry 4.0 and logistics 4.0 concepts as explained above. Their reluctances are numerous as presented in [8], they are afraid of:

- New technologies. These technologies are the sign of changes, and then the loose of self-control, habits, their organization, etc.
- Artificial intelligence and automation. They generally consider these techniques as negative for human in their companies. Even if technical evolutions are benefits, the complexity and the necessary training are real brakes.
- Investments cost regarding expected benefits. Changes necessary for implementing industry 4.0, in terms of software and technologies are generally expensive for them.
- The disappearance of their familial and social atmosphere (social and societal policies).

2.3. Levers for accelerating Industry 4.0 implementation in SMEs

Levers for accelerating industry 4.0 and logistics 4.0 implementation in SMEs corresponds to responses for solving brakes presented above. In addition to a necessary structuration of convincing argues, a SME adapted framework has to be defined as explained in [8].

In the literature, sustainability is presented as an important criterion of industry 4.0. It is only studied through environmental dimension integration on industrial solutions as shown in [9]. In addition to environmental dimension, social and societal dimensions have to be added in terms of sustainability for convincing SMEs. Workers are the basis of any SME, and in the future, their place will be the same. Then, it is important to propose to SMEs, sustainability as the kernel of a new framework also integrating new technologies, organizations, flexibility and adaptation to the market.

2.4. Reasoning for problem solving methods

Levers accelerating industry 4.0 implementation in SMEs, need to be activated for solving concrete SMEs problems. Many reasoning will be use in this case for elaborating the adapted problem-solving method for encouraging and realizing industry 4.0 implementation in SMEs. Reasoning used in this case are:

- Decomposition reasoning,
- Transformation reasoning,
- Case-Based reasoning (CBR) [10].

The method solving problem which is developed combines these three reasoning with multi-agent systems (mainly learning agent) [11] for improving company performance. Learning agent are used in the frame of CBR process as presented in [12].

The idea is to study problems associated to a company and solve them by using old cases. But the system uses could learn from each new experience and improve solutions capitalized in its knowledge base.

2.5. Formalisms for developing a decision aided tool in order to implement industry4.0 concepts in SMEs

Subjects developed in the literature and which will be used for involving SMEs in the implementation of industry 4.0 concepts, are also related to artificial intelligence. Indeed, concepts of expert systems have to be exploited for

developing a decision aided tool. As explained in [13], an expert system architecture is mainly composed of components presented in the figure 1. This architecture will be completed by specific modules for elaborating the adapted aided tool for solving industry 4.0 concepts implementation in SMEs.

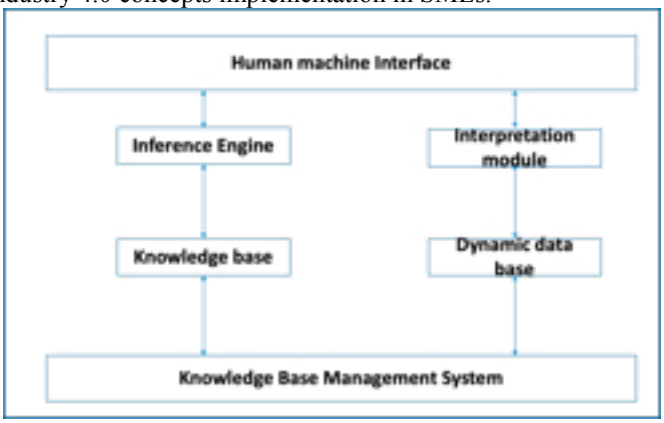

Figure 1: structure of an expert system

The elaborated framework is presented in the following chapter.

3. New framework for implementing Industry4.0

The objective of this framework is to encourage industry 4.0 and logistics 4.0 implementation in SMES. Brakes to industry 4.0 implementation have to be taking into account for finding causes of SME reluctances. Then, levers for accelerating Industry 4.0 implementation could be defined. Four aspects are defined for making this implementation a success for the company:

- New technologies & tools for increasing company global performance
- Organization for structuring company processes and functioning.
- Flexibility and changes management for adapting in real time the company response to market requirements.
- And Sustainability as the kernel of the framework.

The approach associated to the implementation in SMEs is presented in figure 2.

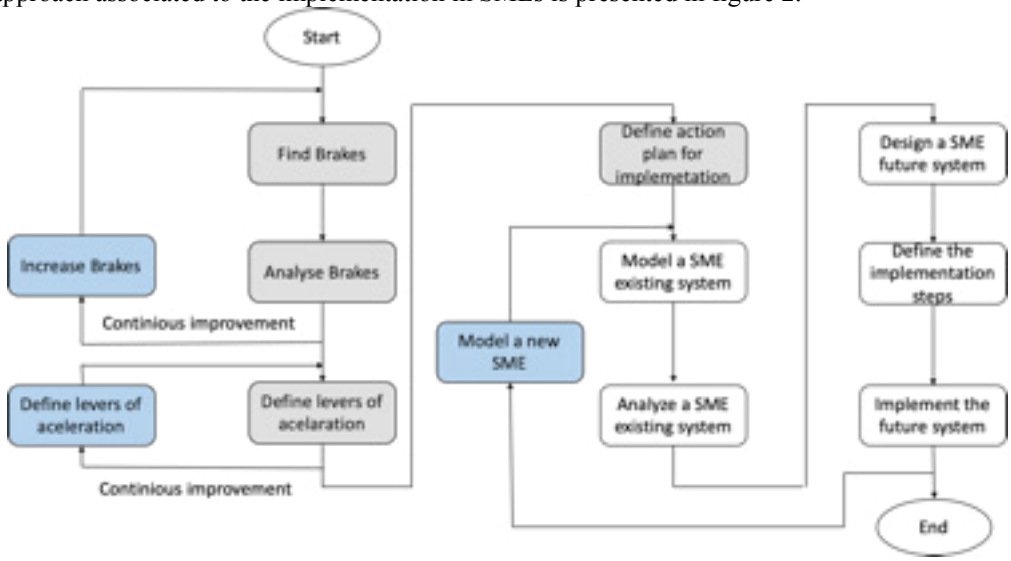

Figure 2 Approach of Industry 4.0 implementation in SMEs

The problem-solving method associated to this framework (and the aided tool being developed) is organized around four main steps:

- Brakes detection and analysis,
- Implementation acceleration levers definition and deployment
- Existing SME system modeling (actual modernizing level) and analysis (detection of inconsistencies and dashboard & KPIs utilization)
- Definition of the future system and implementation plan.

Reasoning are combined for realizing each step. The idea of a reference model defined according to a company activity sector is important because new technologies, organization, flexibility & changes, and sustainability could be associated to this sector and the use of particularization reasoning will allow to define the adapted solution to the SME studied. The capacity to capitalize knowledge associated to old cases is also an advantage for solving (new case) problems and implementing industry 4.0 in a new SME. Each new case contributes to improve the reference model, brakes, levers etc.

This framework (figure 3), in opposition to many architectures presented in the literature, considers sustainability as the kernel of industry 4.0 concepts implementation in SMEs. Indeed, new technologies (RFID, IoT, Robots, Cobots, etc.) & tools (WMS, ERP, MES, etc.) are important for increasing the company performance, and solving technologically problems like traceability (tracking), errors, products quality, etc. New organization (Blockchain, etc.) and flexibility & changes management are also important for defining the future of the company and implementing step by step industry 4.0 concepts. But, sustainability described by environmental, social and societal aspects must highly participate to the definition of this company future. Thus, in this framework three sub-systems could be defined for a company as shows in figure 3. The idea is to model, analyze and improve each sub-system of the SME being studied and to define best steps for industry 4.0 implementation in the company. At each step of the framework utilization, the loop elaborated around sustainability will continuously be used.

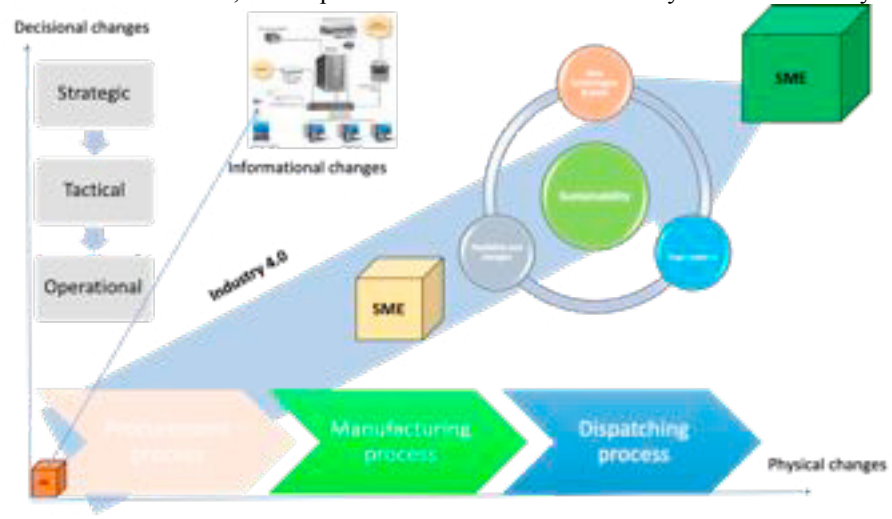

Figure 3: Framework for Industry 4.0 concepts implementation in SMEs

4. The decision aided tool for implementing Industry 4.0 in SMEs

The framework presented above, is supported by a decision aided tool for structuring data collected in SMEs. The architecture of the decision aided tool is presented in figure 4. This software being developed in Icam, is composed of:

- A user interface for managing interaction with the company being studied.
- A tool manager for managing relation between modules of the software tool.
- An existing system module for working in detail of a company case.

- A CBR system for managing old cases and using them as an aid for improving the actual case
- An expert system containing a rule base, a fact base, an expert knowledge module and an Inference engine. Data acquired on an activity sector are transformed for being used in order to analyze a company of the sector and improving its performance. expert knowledge could continuously be capitalized.
- A Brakes management system for finding brakes to industry 4.0 concepts implementation
- An acceleration levers system for defining levers for accelerating industry 4.0 concepts implementation in SMEs.

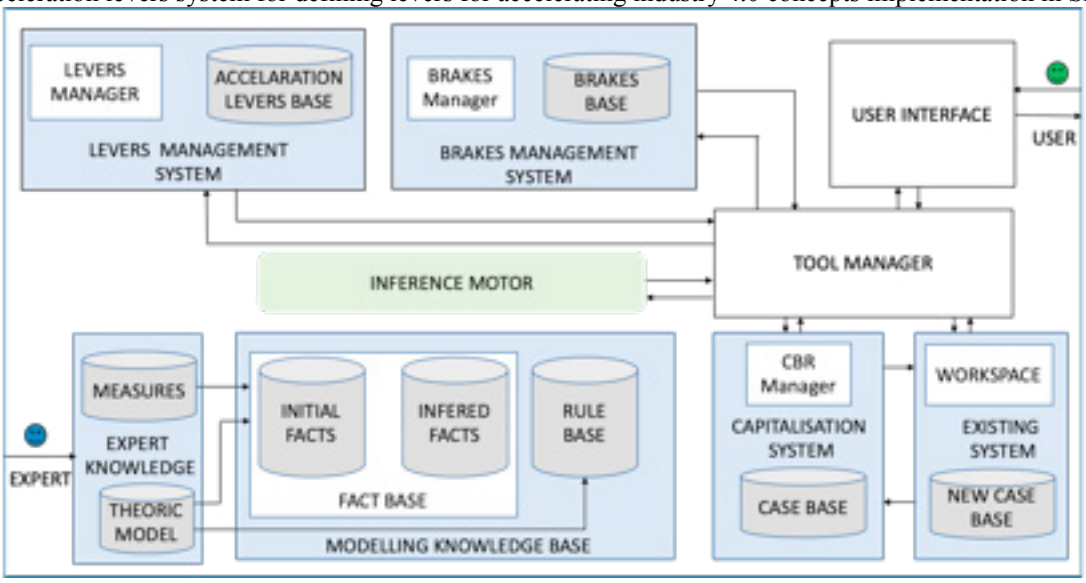

Figure 4: Architecture of the decision aided tool

5. Illustration

The example presented in this paper allows to validated concepts elaborated above and to show how the framework and the decision aided tool will be used for implementing industry 4.0 concepts in SMEs.

Many activity sectors are actually being studied in order to find brakes for companies of this sector, deduce levers accelerating industry 4.0 implementation in these companies, and define a reference model of the sector.

The process used for a study is presented in figure 5. This process is issued from a combination between DMAIC (Define, Measure, Analyze, Innovate, Control, (and Standardize)). The general approach explained above is also in phase with this process. The first step of the process corresponds to company observation and modelling. Then, results could be analyzed, the new model designed and implemented for experimentation.

The sector presented is agricultural equipment sector. The company presented in this example is a group, but the study was on one of their autonomous factories, organized like a SME. The company is located in the north region of France (not far to Paris). The objective of the study was to improve its global performance. Then it was a good opportunity for testing concepts elaborated above.

Firstly, an audit was made for finding brakes for industry 4.0 implementation in this company. Reasons were basics:

- Concepts and tools are not adapted to agricultural domain
- They don’t take into account expectations of our customers (farmers)
- They are mainly destined to big companies
- They are defined for finding jobs to consultants (i.e. ERP, WMS, MES choice and implementation)
- They are not defined for helping our workers
- We are not ready to change, because everything is ok now and we don’t want disturbance
- We are afraid about safety and cloud utilization
- It is to expensive to my customers to pay new technologies in products

- Etc.

All these brakes were capitalized in the brakes modules in order to be available for defining solutions to each of them in order to accelerate dynamics of industry 4.0 implementation.

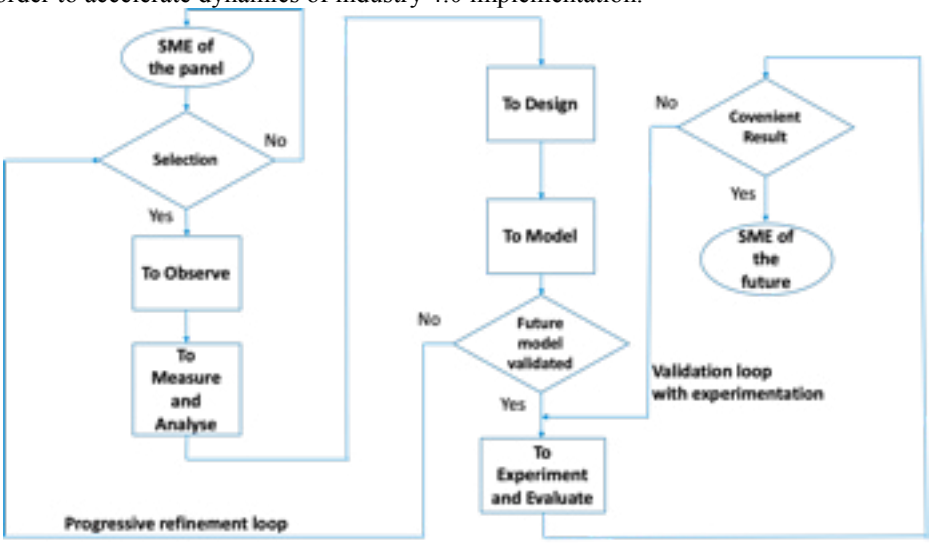

Figure 5: Process for implementing Industry 4.0 concepts in SMEs

Secondly, a discussion with the staff and workers allow to find levers for accelerating industry 4.0 implementation in this company. Two of these levers were to convince them about advantage of the new framework and the ability to adapt step by step the implementation of industry 4.0 concepts to their company. Indeed, the framework with sustainability as kernel was appreciated. Its takes specificities and human being of the company into account for defining new technologies to implement and new organization to deploy. Flexibility and changes introduce the opportunity to increase progressively the company performance.

Then, an audit was done in the company for realizing the modeling of the company existing system for measuring the actual degree of modernization. The decision aided tool was used for elaborating all company models. Thus, the model analysis allows to detect inconsistencies. The expert system and rules defined for this analysis was used for determining these inconsistencies. For instance, the company has difficulties of communication in the storage management area. This inconsistency causes non respect of orders procedures, confusion of communication tools, and no following of orders. It was opportunity to convince workers about the necessity to increase the service performance (and their personal performance) by exploiting new technologies (RFID, existing tools) and organization. Social aspects were used as a priority in the definition of the new organization. A co-creation and co-design process had been utilized in this case. The capitalization module of the decision was not sufficiently rich for providing an old case for aiding in the new design, but a reference model was defined for communication and had been used for obtaining the solution as shown in figure 6.

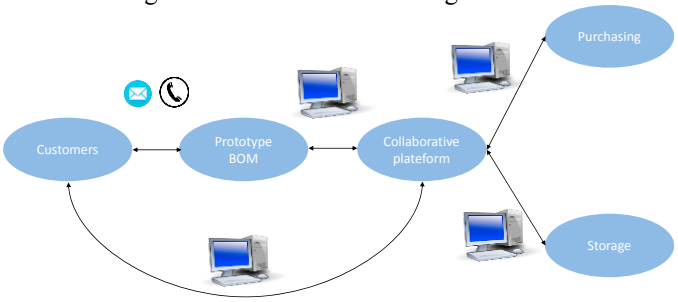

Figure 6: Reference model for communication

An implementation plan of 4 years was defined for this company and it is deployed step by step according to the company financial capacity and in coherence with staff and workers (co-design and co-creation) by thinking at first about sustainability and using new technologies, organizations and flexibility as tools for satisfying sustainability increasing.

6. Conclusion

Brakes for Industry 4.0 and logistics 4.0 implementations in SMEs are numerous and levers for accelerating dynamics of implementation have to be exploited in order to increase continuously the company performance. Thus, the development of a new framework with sustainability as kernel contributes to aid companies (SMES) in the necessary digital and technological transformation of their structure for being efficient. In this paper, in addition to the sustainable framework and the corresponding problem-solving method, the architecture of a decision aided tool for accompanying SMEs in industry 4.0 and Logistics 4.0 concepts implementation has been presented. Reasoning (CBR, decomposition, transformation) are combined with artificial intelligence (Expert system, multi-agent systems, learning agents, etc.) for elaborating this tool. Co-creation and co-innovation structure were proposed for solving company problems. An illustration was given for explaining how the software tool and the framework could be used for increasing SMEs performance.

The decision aided tool being developed in Icam will contribute to accelerate dynamics of industry 4.0 and logistics 4.0 implementation in SMEs. This implementation is indispensable for European SMEs for being competitive and efficient on the world market.

References

[1] I. Gwilt, J. Rolph, I. Eimontaite, et al. (4 more authors), Cobotics: developing a visual language for human-robotic collaborations, Proceedings of the Cumulus Conference 2018, Cumulus conference Paris 2018 – To get there: designing together, Paris, France. Cumulus (In Press), (2018).

[2] R.H. Weber, R. Weber, Internet of thing, Legal perspectives, Springer, (2010).

[3] L. Atzori, A. Lera, G. Morabito, The internet of things: A survey, Computer Networks, Elsevier (2010).

[4] T. Stock, G. Seliger, Opportunities of sustainable manufacturing in Industry 4.0, Procedia CIRP 40 (2016), 536-541, Elsevier.

[5] C. Santos, A. Mehsrai, A.C. Barros, M. Araujo, E. Ares, Towards Industry 4.0: An overview of European strategic Roadmaps, Procedia Manufacturing 13 (2017) 972-979, Elsevier.

[6] B. Tjahjono, C. Esplugues, E. Ares, G. Pelaez, What does Industry 4.0 mean to Supply Chain? Procedia Manufacturing 13, (2017), 1175-1182, Elsevier.

[7] V. G. Frolov, D. I. Kaminchenko, D. Y. Kovylkin, J. A. Popova, A. A. Pavlova, The main economic factors of sustainable manufacturing within the industrial policy concept of Industry 4.0, Academy of Strategic Management Journal, Volume 16, Special Issue 2, 2017.

[8] Dossou, P.E 'Impact of sustainability on the supply chain 4.0 performance', in Procedia Manufacturing (2018), Elsevier, being published reference: PROMFG 29040, 2018

[9] P.E. Dossou, M. Nachidi, Modeling Supply Chain Performance, Procedia Manufacturing Elsevier, 11C (2017) 838-845

[10] A. Aamodt, Case-Based Reasoning: foundational issues, methodological variations, and system approaches, Artificial Intelligence Communications, 7, (1), (1994) 39-59.

[11] Ferber, J. Multi-agent system: An Introduction to distributed Artificial Intelligence, Harlow, Addison Wesley Longman, ISBN 0-201-36048-9

[12] S. Sen, G. Weiss, Learning in Multiagent Systems, Ed., Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence, Chapter 6, The MIT Press, Cambridge, MA, (1999) 259-298.

[13] L. Hu, C. He, Z. Cai, L. Wen, T. Ren, Track circuit fault prediction method based on Grey theory and expert system, J. Vis. Commun. Image R. 58 (2019), 37-45, Elsevier.