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ScienceDirect

Procedia Manufacturing 38 (2019) 1181–1188

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

29th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM2019), June 24-28, 2019, Limerick, Ireland.

Project Management during the Industry 4.0 Implementation with Risk Factor Analysis

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Abstract

This paper analyses the process of Industry 4.0 implementation into the companies. The main purpose of this article was to determine the project framework for implementation of Industry 4.0 concept. The first part describes the basic principles of Industry 4.0 concept and 7 phases of Industry 4.0 implementation process. The second part describes the current state of art in the field of the project management in company with Industry 4.0. The third part deals with the implementation of Industry 4.0 project phase description and the definition of used methodology. The next part consist of the methodology application for the definition, evaluation and suggestion of solutions to reducing the risk threads for the typical production company in middle Europe. The last part deals with the project team members recommendations in case of small, medium and large companies.

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Peer-review under responsibility of the scientific committee of the Flexible Automation and Intelligent Manufacturing 2019 (FAIM 2019)

Keywords: Industry 4.0; Project management; Risk Management; Digital twin

1. Introduction

The new manufacturing technologies have always been the advantage for each company because it ensure more fast and flexible production. The new technologies gradually caused development of industry to the concept of new industrial revolution called Industry 4.0. The main vision of the concept is the transformation of current factories or creation of new smart factories.[1] These smart factories (sensors, machines and IT systems) will be connected to the production facilities called Cyber-physical systems (CPS). [2] This concept consist of autonomous robots, Internet of Things (IoT), big data, simulations (digital twin), horizontal and vertical system integration, cloud computing,

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Peer-review under responsibility of the scientific committee of the Flexible Automation and Intelligent Manufacturing 2019 (FAIM 2019)
10.1016/j.promfg.2020.01.208

cybersecurity, additive manufacturing and augmented or virtual reality. Application of these nine technological fields will change the standard production into the fully integrated, automated and optimized production flow. In connection with the intelligent manufacturing technology is possible to achieve flexible and intelligent manufacturing process suitable for the dynamic market. [3] The implementation of all new technologies and realization of Industry 4.0 concept will bring connection of machines with another machines, humans with humans and humans with machines. These connections create a huge amount of data. These data are called Big data and it is necessary to analyze to for the managing of the current production and the prediction of possible failures. [4] The fast analysis of obtained data is necessary for flexible production planning and managing.

The concept of Industry 4.0 opens new opportunities and research questions. One research question asks about the link of the project management future and its implementation to the concept of Industry 4.0. This paper seeks to answer this research question.

The implementation of all technologies to the current company will be very large and complex process. This process is very similar in many aspects with standard company projects. It follows that the process of Industry 4.0 implementation to the company can be managed as a standard project. For the project, the project team has to be found. The whole implementation project can be realized in one step if the company is small but in most cases the implementation project is too large. In these cases, the most appropriate option to make the implementation is a gradual change in several phases.

- Definition of company vision and strategy for implementation of Industry 4.0
- Identification and description of company processes
- Implementation of fully-fledged information system (e.g. ERP / ERP II) and manufacturing data collection.
- Digitalization of collected data, creation of a digital twin and modification or purchase of machines (based on information from the digital twin)
- Implementation of horizontal integration (i.e. definition of rules that control of production processes and automatic data collection)
- Data analysis and vertical integration (data aggregation for top management and process optimization based on the data
- Self-managed production and logistics (CPS = Cyber Physical System)

2. Literature review

The term Industry 4.0 is now quoted very often. An increasing number of quotes can be found in different citation databases. In our research, we focused more on the context of Industry 4.0 concept and project management with emphasis on risk management. The related paper of Thee Zin Win [5] deals with the problem of project management after the implementation of Industry 4.0. This paper especially describes the differences between the standard project manager and project manager in company with implemented Industry 4.0 concept and their necessary knowledge and skills. The paper of Alberto Cerezo-Narváez [6] describes the model of project management competencies in company with implemented of Industry 4.0 concept. The Luca Rezzani in his study [7] describes also the changes of soft and hard skills of project managers in Industry 4.0 company and the roles of the new Industry 4.0 project managers.

All published researches in this field are focused on the project managers after the implementation of Industry 4.0 concept. However, the implementation an project is very complex process that has to be described, planned and realized with emphases on the risk management of this large project. The aim of this article is to present the project framework for implementation of Industry 4.0 that can be applicable for the project managers during the preparation and implementation of Industry 4.0 concept in a company.

3. Design of framework

3.1. Research Methodology

An important task was to collect data and information for the modification of the proposed methodology framework. Data collection for this case study was conducted using these techniques:

3.1.1. Interview

The interview methodology was used in our case. In this technique, information of management strategy, vision, requirements, risks, impacts and probabilities were collected from the experts.

3.1.2. Brainstorming

Another used methodology was brainstorming. In this technique, the group of experts meet to generate new ideas and solutions (in our case the risks identification) around a specific domain of interest by removing inhibitions. People are able to think more freely and they suggest many spontaneous new ideas (e.g. risks) as possible. All the ideas are noted down, those ideas are not criticized, and after brainstorming session, the ideas are evaluated.

3.1.3. Semi-quantitative risk assessment method

The semi-quantitative risk assessment method is the second methodology used in our research. In this methodology, the risks were identified from the information from experts in the first step. Then, impact (I) and probability of occurrence (PoO) were established for each risk. The scales used to characterize the probability of occurrence can be different in semi-quantitative approach. [8] The impact of risk can be classified by the risk value into several categories. The most common categories of risk impact are low, medium, high and very high. The risk value (RV) is calculated according to the equation below. [9]

$$Risk\ value\ (RV) = Impact\ (I) \times Probability\ of\ Occurrence\ (PoO) \quad (1)$$

The probability of occurrence (PoO) is determined by the possible occurrence of the incident. Levels and values setup for the PoO in our case are shown in Table 1.

Table 1. Setup levels and values of probability of occurrence.

Probability of occurrence (PoO)					
Value	1	2	3	4	5
Level	Rare	Unlikely	Possible	Probable	Highly probable

The impact (I) of the risk describe the significance of the risk when the risk occurs. Levels and values setup for the I in our case are shown in Table 2.

Table 2. Setup levels and values of impact.

Impact (I)					
Value	1	2	3	4	5
Level	Very low	Low	Medium	High	Very high

The calculated risk value (RV) can be between 1 to 25 due to the established I and PoO. If the RV is less than 4, the risk is evaluated as low. If the RV is between 4 and 9, the risk is evaluated as medium. If the RV is between 10 and 19, the risk is evaluated as high. If the RV is more than 19, the risk is evaluated as very high. The urgency of risks solving is determined based on the risk value.

3.2. Generic methodology framework

The proposed methodology framework contents 7 selected phases. It is more suitable to split the implementation project to more partial projects. These partial projects can be identical with implementation phases. These individual phases have been defined based on the literature review and may be implemented as part of one large project or can be implemented as a separate sub-projects. It depends then on the size of the organization.

3.2.1. Phase 1 – Definition of company vision and strategy for implementation of Industry 4.0

The vision and strategy of the company due to the industry 4.0 implementation have to be defined by the top management in the first phase.

3.2.2. Phase 2 – Identification and description of company processes

After the definition of vision and strategy, the process engineers have to identify the company processes. Then the description of important processes have to be realized.

3.2.3. Phase 3 – Implementation of fully-fledged information system (e.g. ERP / ERP II) and manufacturing data collection

The fully-fledged information system has to be implemented and it will be also necessary to collect all manufacturing data for later digitization.

3.2.4. Phase 4 – Digitalization of collected data, creation of digital twin and modification or purchase of machines

In this phase the digitization of all collected data from previous phase is necessary. In this phase, the digital twin of the company will be designed and tested. Then the digital twin will be filled by the real data from previous phases and the information from this simulation will be used for modification or purchase of machines.

3.2.5. Phase 5 – Implementation of horizontal integration

In this phases, the new or modified machines from the phase 4 will be implemented to the manufacturing process and cause the process reengineering. In this phase, the current labors have to be re-trained. Also the new control rules have to be defined and implemented. This phase also provide the new data from the automated machines because it will have telemetric and diagnostic unit and will be connected to the network. It follows that the new (previously not recorded) data will be collected and can be analyzed. Due to this new data, the data model of company in the information system will be changed and the data amount will be increased in this phase. These big data will be important in the next phase.

3.2.6. Phase 6 – Data analysis and vertical integration

The data collected in the previous phases will be processed by sophisticated methods in this phase. For that task, the many data analysts will be necessary. It could be problematic part of the Industry 4.0 implementation because it is not possible to use current employees and improve their skills by re-training because the data analysis is very complicated field. The data analysts have to have knowledge from the data analyst in the field of the company.

In case of the small company the data analysts need knowledge of data analysis, but also of the production process. The reason for that is to delegate the production process for the data analysts due to the financial reasons. In large company will be the close cooperation between departments, to have a properly controlled production process. For example IT department will cooperate with the process engineers and quality controllers.

3.2.7. Phase 7 – Self-managed production and logistics

In the fourth phase we will have an almost autonomous production. The manufacturing process will be self-optimizing with the maximal productivity.

These 7 phases should be very similar for each production company. The differences will be primarily in their production processes, the supporting and managing processes will be similar. The production processes can be simulated by the digital twin. The results from the simulation will be the key factor to the successful project of Industry 4.0 implementation. For the successful implementation of the phases described above, attention must be focused to risk management and the project team. The reason is fact that the concept Industry 4.0 introduces new requirements for both, risk management and project teams.

4. Risk analysis

The methodology described in the previous chapter was practically used in our research. In the first step, the interview with experts was realized. The information from the interview were collected and then the brainstorming methodology was used to the risks identification. Then, the semi-quantitative risk assessment method was used. The risks were identified by brainstorming and divided into several risk groups - Financial, Information, Technical, Social and Environmental. Then the risks were evaluated in cooperation with the expert. The list of identified and evaluated risks can be see in Table 3.

Table 3. The list of identified and evaluated risks.

Risk group	Identified risk	PoO (Probability)	I (Impact)	RV (Risk value)
Financial	Poor cash flow	3	4	12
	Market risks (decrease in profits)	3	3	9
	Lack of money for maintenance and operation	3	4	12
	Credit risk	3	3	9
	Not allocating the subsidy	2	2	4
	Incomplete and inaccurate cost estimates	3	2	6
Information	Errors in plan of implementation Industry 4.0	3	2	6
	Errors in design	3	5	15
	Errors from suppliers information	4	2	8
Technical	Shortages of required machines	1	4	4
	Not realistic gant chart - errors during the estimated time	3	2	6
	Delay of project	3	2	6
	Lack of cyber security	3	4	12
Social	Theft and insecurity	1	3	3
	Vandalism	1	4	4
	Shortage of skilled labours	5	4	20
	Labours strikes	2	3	6
Environmental	Earthquake	1	3	3
	Fire	2	4	8
	Lighting	3	2	6
	Flooding	2	4	8
	Wind damage	3	2	6

This table presents the theoretical risks evaluation for the typical production company in middle Europe. For each specific company we can recommend new determination of probability and impact and recalculation of risk values. In our case, we found four high risks and one very high risk, which should be solved preferable before the implementation project starting. Suggestion of risks mitigation for the high and very high risks is follows. In case of the poor cash flow risk, the best solution is to make a sufficient financial reserve before the start of the Industry 4.0 project implementation. In case of the lack of money for maintenance and operation, the project team should also ensure financial reserves for the pilot operation. In case of errors in design the team should thoroughly examine the design of Industry 4.0 in their company (if the design is correct). In case of lack of cyber security the consultation of current cyber security with cyber security experts is suitable in the first step. Then the most problematic topics should be solved immediately. Also the regular cyber security analysis should be realized. Last but the most important is to eliminate the shortage of skilled labours. The long-term solution is the collaboration with universities, specification of requirements and recruitment of precise skilled labours from the universities. The disadvantage of that solution is the necessary time (many years). The short-term solution is the headhunting of key labours and training of current available labours.

5. Project team description

In this section, the most suitable structure of project team is described. This recommended project team has many different roles. For the small or medium companies, this team can be unacceptable due to the economic reasons. It follows that for medium companies can be necessary to have less people in the project team and some roles can be merged into the one people. In the small companies, only a few people or one people can replace the project team if it is necessary.

5.1. The recommended project team (especially for large companies):

- Process engineer
- Data analyst
- Representative of the top management
- Quality engineer
- Production manager
- Software engineer (digital twin)
- Maintenance manager
- Cyber security analyst
- IT support
- Logistics manager

5.2. The partially reduced project team (especially for medium companies):

- Data analyst & IT support & Cyber security analyst & Software engineer
- Representative of the top management
- Process engineer & Quality engineer
- Production manager & Maintenance manager
- Logistics manager

5.3. The fully reduced (basic) project team (especially for small companies):

- Data analyst & IT support & Cyber security analyst & Software engineer
- Representative of the top management (or company owner) & Production manager & Maintenance manager & Logistics manager
- Process engineer & Quality engineer

After the finishing of Industry 4.0 implementation, the project team will have the maximal knowledge and information about the system in company. This is the reason why the project team will be necessary for system changes or problems solving. In some cases (especially small or medium companies), holding of the project team after the finishing of implementation Industry 4.0 may not be economical. The possible way to solve that problem is outsourcing of the project team for the implementation. This external project team can solve the implementation by remote control and digital twin of company. In addition, the members of project team can be physically placed in the world and work together remotely. It follows that one project team can solve the implementation and administration of Industry 4.0 in dozens of companies which pay regular fee for administration and save the money on their own employees. On the other hand, this solution is susceptible to abuse and it is necessary to solve the cyber security. In the case of the large companies, the project team can be intern but can consist of the employees from different branches of the company and also work together remotely.

6. Conclusion

The implementation of Industry 4.0 to the manufacturing company is very demanding process consists of many activities. These activities have to be planned and managed and it is possible to designate this process as a project. The main purpose of project management is effectively achieved the desired goal which is still valid in case of the Industry 4.0 implementation project. This project is very complex and in most cases is suitable to divide it into a several smaller project phases. These phases were defined and described in the paper and the optimal project framework was determined. The project phases are very similar for each manufacturing companies in case of the supporting and managing processes. The main differences are in their production processes, which it is appropriate to simulate them during the Industry 4.0 implementation in the digital twin.

The risks of the project implementation were described and evaluated by the semi-quantitative risk assessment method. These risks were identified and evaluated for the typical production company in the middle Europe, where the critical risk is shortage of skilled labours. The problematic risks are errors in design, poor cash flow and lack of money for maintenance and operation. These risks can be mitigate by creating of larger financial reserve before the starting of Industry 4.0 implementation. Then the thorough check of the Industry 4.0 design before the implementation. Last but not least it is necessary, in short-term solution, thorough training of available labours, acquirement of key labours by headhunting despite increased key labours cost. In long-term solution it is suitable the collaboration with universities and the acquisition of appropriately educated labours directly from the universities. For each specific company the recalculation of risk analysis is recommended.

The most suitable project team for the implementation of Industry 4.0 was also defined. This team consist of 10 important roles for the implementation in large companies. Some of the roles were merged and 5 roles was created in case of the implementation in medium companies, where these 5 roles will be sufficient. In case of the small companies, these 5 roles were more merged and the basic 3 roles were founded. These 3 roles are necessary for the Industry 4.0 implementation project. Possible option is also outsourcing of the project team. This option can be a more economical alternative for small or medium companies, where long-term costs for maintenance and small changes can be lower than in case of the own project team labours. Future vision can be replacement some roles in the project team by artificial intelligence.

Acknowledgements

This research has been supported by the Ministry of Education, Youth and Sports of the Czech Republic under the RICE – New Technologies and Concepts for Smart Industrial Systems, project No. LO1607 and by the Technology Agency of the Czech Republic, project No. TH02010577 “Software platform for Implementation Accelerating of Process Control and Automation Systems” and by the ESF project of University of West Bohemia, project No. CZ.02.2.69/0.0/0.0/16_015/0002287.

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