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Managerial model of business performance in industry 4.0 concept concentrated on effective manufacturing process

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Abstract

A mutual combination of various managerial conceptions claims a lot of new opportunities for production managers, such as how to influence effectiveness and efficiency of flexible production flows based on the industry 4.0 concept. This paper is concentrated on the research of actual conditions, active influencing real manufacturing processes and their special process stability as a basic assumption for flexible implementation of industry 4.0 in industrial enterprises. In the real production process, the horizontal managerial concept is confronted with the vertical (digitised) manufacturing concept. The results presented in this paper are based on the research and survey realised in various industrial companies.

Keywords: Process, model, industry 4.0, flexibility.

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1. Introduction

Companies can be successful in any industry, but only if they use their intellectual capital to find sources of competitive advantage. Process innovation in production and administration processes must be reflected in human performance systems, processes and completely production technology. Implementation of the industry 4.0 concept strongly depends on the right understanding of people, integrated in this new change processes in the 4th industrial revolution. Business performance can be defined as an effective combination of managerial, technical and information factors, whose mutual combination leads to the real possibility of flexible and optimal realised production flows oriented to the customer's order satisfaction in real time. The core goal of business performance is to fulfil the operative goals, concentrated in the production flow and their value added. Our key aim here is adequate performance management, concentrated on the technical site (input data structure and quality), organisational site (structure and organisation of production processes) and information site (e-processes, structure and level of automation and digitised technologies).

Many companies are oriented on the 4th industrial revolution; they solve daily a lot of new working situations in management and organisation of own production processes. The purpose of this paper is to present a methodological tool for motivation of own staff by implementation of the industry 4.0 concept. It is most important by this concept to manage and lead all employees for effective and profitable communication with e-technologies used in company. Important dates for the methodology proposal were taken from surveys realised in selected industrial companies (2015, 2016), oriented on the implementation of industry 4.0 concept in three countries. According to the results achieved, quantitative and qualitative analyses were realised and identified core motivation trends for effective e-processes. The presented results show key parameters and orientation strategies for flexible employees' motivation, integrated in process teams in the area of production planning and organisation. It is important to use various motivation strategies, dependent on the process – product – personality motivation of employees. This methodology proposal has limitations in the small amount of companies that have implemented the industry 4.0 concept. If we are interested in the new production management strategies in this environment, we should take positive and negative feedback from existing companies for effective new man–man strategies connected with e-processes. The research and results presented in this article open new ways of managerial strategies for production departments and industrial enterprises in the era of the 4th industrial revolution. Many companies focus their attention solely on the implementation of e-technologies and e-processes, while paying still less attention to an equally important element – human. Practice will help this methodology to optimise the man–man cooperation and teamwork for profitability of complex e-production systems and e-technologies. This paper extends the managerial strategy configuration model, highlighting new ways of man–man strategies that motivate company employees to effectively cooperate with new-implemented e-technologies in order to achieve the optimal process performance.

The main goal of this paper is to present the core parameters of process innovation methodology, which enables to achieve real results in a relatively short time. The core output of the presented methodology is a complex way of mutual connection of people, knowledge and skills, effective connection of man–man production, conception integrated with e-processes and administration systems in enterprise. The results demonstrate that SMEs have limited awareness of the risks associated with underinvesting in the process innovation system.

2. Theoretical background of effective managed manufacturing process

Modern production concepts dispose with a strong potential to change the way factories work. It may be too much to say that this is another industrial revolution. Traditional production concepts were oriented on high productivity, low cost and acceptable customer time. Most new digital technologies have been brewing for some time. A lot of manufacturing companies have great potential for improvement in the area of 'human–machine interfaces' and in man–man interfaces, according effective utilisation of digital technologies. We surveyed more than 300 manufacturing companies during 2015–2016; only 25% of manufacturers consider themselves ready for industry 4.0. The coming of steam power and the rise of robotics resulted in the outright replacement of 60–75% of industrial equipment. All industrial companies have a lot of experiences with various models of people management in traditional production processes, but in strong connection with e-technologies we should find new concepts, based on the right compatibility of e- technologies and people (Chromjakova, 2016). Of particular importance is the understanding of new types of process communication: e-technology cooperates with staff, and staff should understand the right way of abilities and potentials of new technology.

The industry 4.0 concept can be characterised as follows: big data, networking, digitalisation, automation, Wi-Fi connection and cloud computing. A lot of effort will be invested in the restoring of old data to the latest IT standards. Special layers are used to transfer the experience of all employees into comprehensive IT systems. A lot of money will be invested in development of exclusive software solutions that help us in industrial enterprises to look forward to the digital future.

In recent times, traditional manufacturing is upgrading and adopting industry 4.0, which supports computerisation of manufacturing by round-the-clock connection and communication of engineering objects (Shafiw, Sanin, Szczerbicki & Toro, 2016). Decisional DNA-based knowledge representation of manufacturing objects, processes and system is achieved by virtual engineering objects, virtual engineering processes and virtual engineering factories. Decisional DNA features as tools for effective industry 4.0 implementation and can facilitate in real time critical, creative, and effective decision making.

Manufacturing IT and industry 4.0 is the fourth industrial revolution with a potential of 12 billion Euros in Germany's chemicals industry (Gentner, 2016). But Switzerland is currently the best prepared of all countries in Europe. Many of the ideas are still very vague. As projects in manufacturing IT and industry 4.0 are different from the classical technical projects other strategies, for example agile project management, are necessary to secure success.

To capture emerging opportunities and keep pace with the rapidly advancing technological frontier, industrial players need to act in three dimensions:

- reach the next horizon of operational effectiveness
- adapt business models to capture shifting value pools and
- build foundations for the organisation's digital transformation by developing digital capabilities, enabling collaboration in the ecosystem, managing data as a valuable asset, and coming to grips with cyber security.

In the realistic, hands-on production environments of our digital model factories, we will accompany the digital journey – across all stages, from interactive training in a digital diagnostic, through to an evaluation of your digital solutions, through to the process of building organisation's digital capabilities (McKinsey Company).

The future research directions include the measurement of organisational culture in firms that have implemented lean processes. This would be a step towards looking at the effect that the different quadrants in the competing values framework have on various elements of lean efforts. This would take a significant amount of work, because the manufacturing industry, the leader in implementing and sustaining lean processes, may have institutionalised particular organisational cultures. It would be an interesting step forward in understanding how lean processes are operationalised across different firms and industries. However, there are multiple ways to examine culture; the authors believe this method allows the capture of the entire spectrum (Pakdil & Leonard, 2015).

A common thread in various approaches for noise removal, model reduction, feasibility reconstruction and blind source separation, is to replace the original data with a lower dimensional approximate representation obtained via matrix or multi-directional array factorisation or decomposition. Besides these transformations, a significant challenge of feature summarisation or subset selection methods for big data will be considered by focusing on scalable feature selection (Snasel, Nowakova, Xhafa & Barolli, 2017).

Manufacturing processes are heavily influenced by virtualisation and increasing networking capabilities. The ‘Internet of Things’ spreads across all industries transforming isolated production cells to members of large communication, logistic and manufacturing systems. But not only production, also the preceding engineering processes suffer from rigid procedural workflows, hierarchically dominated decision-making structures and numerous media breaks. It is therefore inevitable to include the product development within this new concept of industry 4.0, linking real and virtual products to the manufacturing world. The aim is to generate structures and descriptions of products, which define a new product completely in digital terms, so that it becomes transparent and understandable in all its facets both in the initial stage of formation and to its future. A digital image or model, also called virtual twin, therefore, must be digitally accessible in all product life stages to all stakeholders and actors, who are dealing with the product, so as to maintain service quality and functionality even under changed conditions. This paper considers the associated changes in the future product development process (Grunder, 2017).

Changing production systems and product requirements can be trace for their origin in volatile customer behaviour and evolving product requirements. This dynamic nature of customer requirements has been described as a constantly moving target, thus presenting a significant challenge for several aspects of product development. To deal with this constant and sometimes unpredictable product evolution, cyber physical production systems that employ condition monitoring, self-awareness and configurability principles have to be designed and implemented (Francalanza, Borg & Constantinescu, 2017).

From the perspective of the long-term trends of the global development the information and communication technology (ICT) will last one of the key innovation technologies. Current trends like big data and cloud computing are very popular topics and it seems that they will be even in the next 10–15 years. The document Global trends 2030 (National Intelligence Council, 2012) emphasises this trend and confirms the surveys done by OECD (OECD, 2015). The ICT is understood as one of the fourth key technological areas:

- technologies pertaining to the security of vital resources (food, water, and energy needs),
- new health technologies,
- new manufacturing and automation technologies.

Just because the manufacturing and automation area is crucial for the deployment of ICT and represents also one of the key segments of the portfolio of the Czech economy with the high influence on the labour market, this article is devoted to it (Basl, 2016).

3. Research results

In order to map the actual trends by industrial enterprises oriented on the implementation of the industry 4.0 concept, we had realised during 2015–2016 a survey oriented on the state of implementatation and experiences with this concept. The respondents were 300 industrial companies from the automotive sector (83 companies), mechanical engineering sector (87 companies), electrical engineering sector (48 companies), chemical industry (42 companies) companies) and food industry (40 companies). This study sets out the key factors in international companies in the Czech and Slovak Republiks and Czech and Slovak manufacturing companies face in achieving the digital transformation of their industry and benefitting from exponential e-technologies integrated in the industry 4.0 concept.

In our survey, first we asked about the motivation of each industrial company for implementation of the industry 4.0 concept. A few companies argue that industry 4.0 is something new, they have not clear vision of how they will implement core pillars of this concept, but they see the possibility of significant progress in accordance with new technologies of process realisation and radical technological innovations. Our survey showed that the effort to implement this new concept is in partial progress and that companies will see clear progress and future potential of real process and production outputs and return on investment new market chances in the future. Only 2% of respondents perceived the role of mutual communication of staff and teamwork as a key issue in e-processes, with the important fact that the industry 4.0 concept is perceived as only e-technology, which is not connected with people communication through new levels of mutual communication. A characteristic of this survey is the knowledge (by 94% of respondents) that data and information about processes and products are also available by all departments in a clear, stable and correct version. The core motivation for implementation of the industry 4.0 concept is the availability of these dates and information in real time for flexible process management.

During the research stage, we concentrated on the following research questions:

1. Is your company dealing with implementation of the industry 4.0 concept?

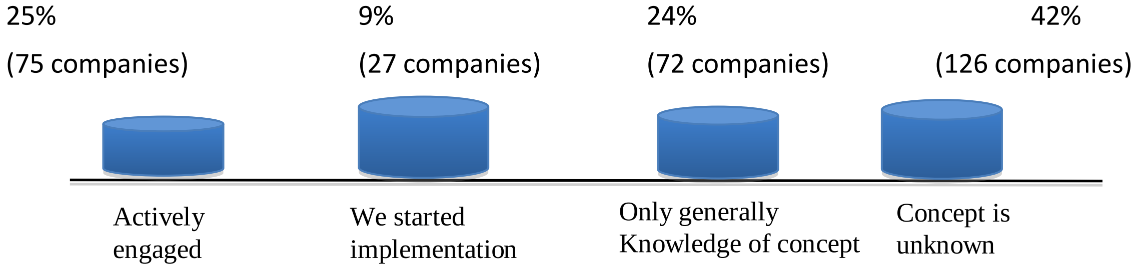

Figure 1. Actual state of the industry 4.0 concept implementation (source: author)

Table 1. Research results oriented on industry 4.0 (source: author)

Industry 4.0 tool	Implemented	Planned for implementation in next 2 years
Robotics	A – 18% (14 companies)	A – 56% (42 companies)
	B – 52% (14 companies)	B – 67% (18 companies)
Mobil equipment, communication	A – 16% (12 companies)	A – 36% (27 companies)
tablets, visualisation tables	B – 74% (20 companies)	B – 89% (24 companies)
Digital production	A – 9% (7 companies)	A – 24% (18 companies)
planning and organisation	B – 19% (5 companies)	B – 48% (13 companies)
Predictive e-maintenance	A – 9% (7 companies)	A – 24% (18 companies)
	B – 67% (18 companies)	B – 77% (21 companies)
Cloud computing	A – 9% (7 companies)	A – 16% (12 companies)
	B – 7% (2 companies)	B – 19% (5 companies)
e-business, e-	A – 37% (28 companies)	A – 47% (35 companies)
communication with supplier or customer	B – 74% (20 companies)	B – 70% (19 companies)
Industrial 3D-print technology	A – 7% (5 companies)	A – 16% (12 companies)
	B – 7% (2 companies)	B – 11% (3 companies)
Smart logistics	A – 7% (5 companies)	A – 12% (9 companies)
	B – 7% (2 companies)	B -11% (3 companies)
Adaptive automation	A – 4% (3 companies)	A – 11% (9 companies)

B–0	B – 3% (1 company)

2. Which real profits/feedback did you achieve in the last year of industry 4.0 implementation tools stage based on the combination with traditional industrial engineering methods?

The verified results showed that most companies used the new industry 4.0 tools with the goal to improve the effects of traditional industrial engineering methods. From A-category 87% (69 companies) it sought to find more intelligent solutions, for example, in the area of flexible production planning and control, productive maintenance and reduction of SMED times directly by selected workplaces. A few companies had the goal to increase the number of e-processes from the area of production processes connected with selected supporting and administration processes – only 23% (17 A-companies). This fact corresponds with our knowledge of the past 5 years, when we had mapped that the companies do not give attention to the systematic structured changes in value added processes in the triangle 'technological changes – process changes – social changes'. That was the reason we began strong orientation on the flexible man–man motivation performance management system for successful and effective implementation of key tools in the industry 4.0 concept.

3. Which core processes for implementation of industry 4.0 had identified industrial companies?

The answer to this question has brought a clear signal to the issue of identification of key business processes. The hypothesis was not confirmed, because all companies have identified key processes mostly in relation to the production process (horizontal core processes), but not in accordance with the implementation of industry 4.0 concept as supporting managerial company process (vertical processes).

As core processes, the following were identified:

- Integration of planning and scheduling processes
- Digitised automation of processes
- Real-time process quality control, online monitoring of production and manufacturing dates
- System based, real-time and end-to-end structured processes and activities
- Personalised and online organised processes
- Customer oriented online order system
- Maintenance of key technologies oriented on online principles
- Personalised and online organised production planning, control and improvement

In accordance with the identification of core processes, we mentioned in our survey the fact that a lot of people in industrial companies have a problem with the right understanding of the 'process' definition. Traditionally, we are oriented on the production processes, supporting processes or we distinguish between managerial or operational processes. In the environment of industry 4.0 concept we should make radical changes in our thinking, because we are speaking about digital company – digital culture – digital processes. Based on this fact we speak about new types of 'process content' according to the digital enterprise environment. From our survey we achieved the following secondary knowledge: most industrial companies have respect before traditional enterprise culture, standards infrastructure, intellectual property protection by workplace, personnel leadership and coaching. This is in direct correlation with the traditional model of personnel security or personnel integrated management and decision-making processes. By these processes the responsibility and delegated competencies by humans, now in the industry 4.0 concept, it is necessary to transfer all important operational business competencies, responsibilities connected with production processes planning, scheduling and organisation to the computer technologies and digital processes.

4. Methodology proposal

The reason we have chosen this area directly lies in the fact that it increases a number of daily communication man–man conflicts and inefficiencies by planning and organisation of production operations. It is true that if we have more through computer and per man organised production processes, we have exponentially more conflicts between these employees. Our methodology will suggest the optimal settings of man–man system to achieve optimal profit from technologies, organised in the industry 4.0 production concept. Every impulse that the worker enters into the system is by nature unique and evokes absolutely accurately described feedback, which is simulated in given software system of selected production technology by machine. It is likely that every impulse, given by the staff, aimed at using the specific functionality of the available technology. The group of multiple e-technologies included in the layout of the production line in a row represents a huge portion of the possible combinations and solutions. Just choose the most suitable for the productive production system and meet the customer requirements are a task, which is supporting in the 'man–man system. Staff motivation for flexible production process is the willingness of an individual worker to realise complexly and productive activity. To manage a flexible production system, we need the right motivated staff, oriented on the readiness to realise operative and strategically process performances.

We identified key parameters of the managerial model of business performance in the industry 4.0 concept concentrated on effective manufacturing process as follows:

- knowledge of stable daily structure of the production programme and available production technologies (elimination of daily changes in production program and higher flexibility during weekly structuring of production programme)
- certainties that stocks intended for the production process are actually available (material, staff, information, standards, layout, material flow, etc.)
- setting clear productions and supporting processes for selected e-technology with regard to the allocation of responsibilities of specific staff (alternative for each shift individual responsible person with clear own e-code in information system)
- readiness of actual dates on daily basis for production planning in information system (motivated man has all necessary information available in right structured information system, he doesn't need manually or with big time wastes looking for all necessary dates)
- adequate working conditions by workplace for seamless realisation of production planning and control (availability of databases, knowledge of performance and technological parameters by e-machines, standards for e-oriented production planning and control, software enabled flexible production planning and control in real time, feedback from unavailable machine capacity in information system just in time)
- proper allocation of competencies and responsibilities by staff linked in a process planning and control network
- possibility (competency) to influence selected parameters of e-technologies by customer requirements in real working day (in cooperation with IT-engineer)
- real feedback from workplaces about realised production losses in information system (realised production amount, re-work pieces, re-typing times, cycle times, maintenance times, etc.)
- competency to stop the production process by the system failure and active corrections in process management system as a preventive action
- possibility of self-realisation by planning – realisation – control of production system in according to balancing the performance management system and innovations given for higher profitability of this performance management system

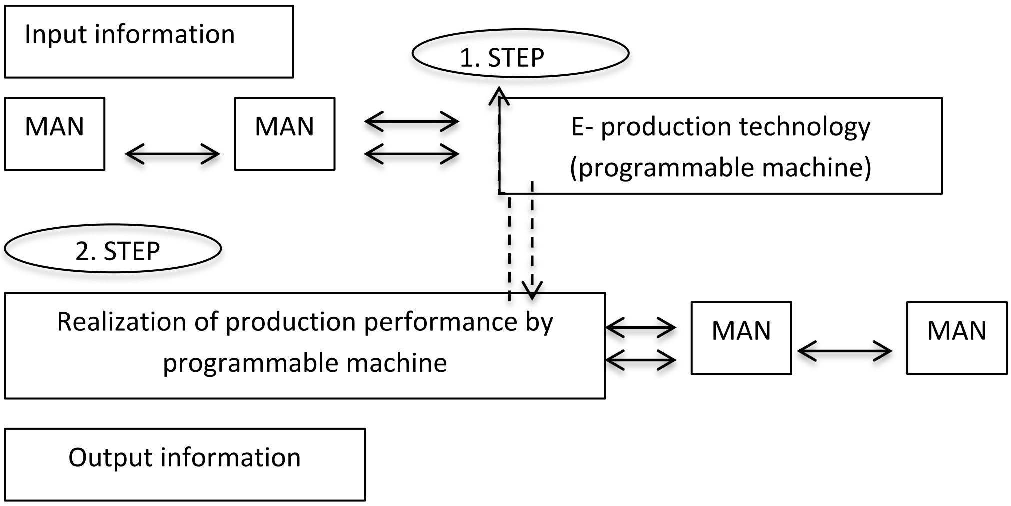

Figure 2. Core structure of managerial model of performance systems (source: author)

In accordance with this model proposal it is important to develop measurable metrics for identification of value added from the industry 4.0 concept in the industrial company environment. Through these metrics we are able to evaluate the positive effects of computerised and digitised production. Following a proposed process stabilisation model, we identify the following metrics for adequate evaluation of results achieved in the process of industry 4.0 concept implementation (Table 2).

The results achieved by testing procedure were important for balancing the motivation performance system setting, the testing showed that enterprises should pay more attention to setting processing parameters of used e-technologies, integrated in industry 4.0 concept, this fact is crucial by the motivation of man–man system. Secondary was declared the right orientation of enterprise management in the product and personality performance management motivation, because these two areas supporting the effective process management and guarantee the satisfaction of each person, integrated in industry 4.0 production system.

Necessary condition for implementation of presented model is existence of man-man system structures between staff positions, integrated in complexly chain of production planning and organisation system. Than we can set the motivation system by given criterions. To adjust the system it applies the basic principle: all tasks must be completed according to the requirements set in the system; in the system there are right instructions for each e-machine, integrated in the industry 4.0 concept. By flexible motivation system is identified the total motivation factor level – it depends from the number of persons integrated in man-man system, by selected workplaces and production processes.

Now it is important to construct simply formula for the definition of complexly employees' motivation of horizontal-vertical system. This formula should bring the clear rule for managers, how to evaluate actual motivation of staff connected with achieved productivity and profitability of their work in the production system and connected with the teamwork in the form of man-man system. For the purpose of development of flexible man-man motivation performance management system for industry 4.0, we propose the following motivation equation:

$$MMMF = Xm_{proc} + Xm_{prod} + Xm_{pers} \qquad (MMMF = 1{,}0)$$

where

MMMF - man motivation factor

m_{proc}- process motivation level

m_{prod}- product motivation level

m_{pers}- personality motivation level

0,5 level of X - full completion of tasks integrated in man-man system, null level of changes or mutual personal/system conflicts (100% satisfaction)

0,4 level of X - completion of tasks in limit given by time, amount of transactions given to the e-process or system (80% satisfaction, 20% of small disruptions or conflicts, may be waiting on the system answer or delivery of right information from other worker integrated in the industry 4.0 system)

0,3 level of X – average completion of tasks by given production plan (50% satisfaction, 50% registration of process conflicts – bad order specification, late order entry, prioritisation of order in one hour, conflicts by persons or system settings)

0,2 level of X – small level of mutual information exchange between staff integrated in

the industry 4.0 system (20% jobs realised by plan, 80% of conflicts or absenteeism of right setting of e-connections in information systems and communication channels by machines

Table 2. Process stabilisation metrics – evaluation tool for managerial model (source: author)

Identification of all core process components integrated in the industry 4.0 concept
Availability of all required functionalities of computerised and digitised technologies
Number of available services integrated in digitised data and cloud system
Number of intelligent drive units integrated in the industry 4.0 concept
Defined technical functionality, virtual functionality, communication capability and model process structure
Communication ability verification by each industry 4.0 system component
Standardisation of e-connections, standardisation of input and output process parameters
Number of objects managed through digitised technology in one e-chain (ID-chain) and by one ID-administrator
Number of process conflicts in pre-implementation stage of the industry 4.0 concept (technical conflicts, technological conflicts, interface conflicts, data cybersecurity)
Number of total digitised processes in production
Number total digitised machines integrated in the industry 4.0 chain
Defined human responsibility for each process component integrated in the industry 4.0 chain
Throughput time of production process before industry 4.0 implementation
Throughput time of production process during industry 4.0 implementation
Real time of system communication by realisation of production process through industry 4.0 system
React time on delivery of system components availability for realisation of production process after input of customer order into system (specification and commitment of customer order)
Operative cost for order processing in digitised environment
Testing and validation of digitised processes in according to the flexible planning and organisation of production process
Ability to re-plan the production process virtually by given instructions through ID competencies for flexible production organisation
Availability of all relevant data and on-line data corrections availability in integrated process components
React time on process defect in system between process component owner (ID) and digitised workplace in production (identified by ID)
Grade of standardisation of interfaces and abilities of units for and digitised regulation of flexible production system
Number of domain borders integrated in digitised environment for production system
Stability and security of defined standards, technological and technical rules, mutual process e-communication and e-management
Number of digital certificates for authentication of realised operations

Number of identities with login data for maintenance and management of operational industry 4.0 system
Definition of system responsibilities for human – guaranty of system timeliness and usability
Number of virtual instances for recovery functions and security incidents elimination in industry 4.0 system

5. Conclusion

Industry 4.0 concept enables radical improve the productivity and efficiency of complexly production value chains, enable to focus on the creative and strategic oriented business activities. Positive effects we can see by workers – this concept enable to organise flexible work in production processes and contributes to higher satisfaction of employees at all enterprises levels through the better work-life balance. Generated potential savings for companies are radical, especially according to the investment and return of investment in IT technologies, customer relationships, production process planning and scheduling and flexible production outputs effects. An important role here is the phenomena of 'collaborative factory', which enables to realise the jobs and process operations in virtual reality by use of mobile workplaces. Each master, supervisor, team leader or shop floor employee can use in their work the assistance of multimodal, user-friendly interfaces through the complexly oriented computerised and digitised technologies, used in industry 4.0. The industry 4.0 concept integrates the three key lines: Internet of things, Internet of services and Internet of people – networks objects, people and systems.

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