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Agile Shopfloor Organization Design for Industry 4.0 Manufacturing

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Abstract

Digitalization changes the manufacturing dramatically. In regard of employees' demands, global trends and the technological vision of future factories, automotive manufacturing faces a huge number of diverse challenges. Currently, research focuses on technological aspects of future factories in terms of digitalization. New ways of work and new organizational models for future factories have not been described yet. There are assumptions on how to develop the organization of work in a future factory but up to now, literature shows deficits in scientifically substantiated answers in this research area. Consequently, the objective of this paper is to present an approach on a work organization design for automotive Industry 4.0 manufacturing. Future requirements were analyzed and deducted to criteria that determine future agile organization design. These criteria were then transformed into functional mechanisms, which define the approach for shopfloor organization design.

Keywords: Organisational design; future work; manufacturing/production systems

1. Introduction

In the past, technology on the shopfloor was always related to a corresponding organizational form. Due to the development known as Industry 4.0 a gap appeared because there is no corresponding organizational form for the factory of the future. Besides technological development, upcoming demographic and global trends also need to be considered in the design of a future agile organization [1] [2].

Firstly, this paper reviews the state of the art literature regarding global trends and demands of employees followed by the factory of the future to provide an overview of future strategic requirements. The strategic requirements are then transformed into criteria and derived into chosen organizational characteristic which present an approach on organizational design. Subsequently, the approach is

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applied by designing an agile shopfloor organization form for automotive Industry 4.0 manufacturing. Finally, a summary concludes the most important aspect of the paper and offer a brief outlook of the discussed topic.

2. Literature review

The literature review for this paper was primarily based on German literature. The reason for this was the focus on German automotive industry. During the literature research one of the objectives was to gain a solid and in-depth knowledge about existing procedures in automotive industry, organizational models, current solutions for industry 4.0 and agile organization of work. As target literature several specialist books from well-established authors and practice-oriented reports from automotive companies were chosen. With the wide-ranging literature review a promising foundation and a fundamental information basis for a future agile organization shopfloor design was laid.

2.1. Global trends and demand of employees

Viewing the worldwide buyer's market, demand is created based on increasingly individualized products with a growing number of variants and a simultaneous shortening of product life cycles [1]. The connection between the high demand of customization and the increasing number of variants as well as the shrinking product life cycles becomes a demanding challenge in the automotive industry [3]. Manufacturers offer models that would not have fit to their strategy ten years ago [4]. Generally, globalized markets are more transparent than ever before which is characterized by customers being well informed, and booming economies result into higher purchasing powers. [5] [6]

Additionally, the industry is aiming for further improvements in production efficiency [7]. High benefits have been achieved due to integration of programmable logic controllers in the past and there are still new fields of use [8]. The next step will be the implementation of elements of Industry 4.0 towards a smart factory, but this occurs to be a transformational process rather than a revolution [9] [10]. The main characteristic of the smart factory is the integration of cyber-physical-systems that are working together in a fully digitalized and interconnected world [11]. They are communicating in the industrial internet of things and their decentralized control units can find the optimum flow of goods in real time which enables them to react quickly and flexible to changes in demand [12].

However, digitalization is not only a key driver and enabler of the move towards smart factories [13], it also offers a high number of opportunities for optimizing business models or creating new business ideas especially data driven optimizations. [14] [15]

Besides those global trends, demographic and social changes, and upcoming generations have great influence on a future organization design, especially in Germany [16]. Nowadays, deciding factors for employee satisfaction in Germany are:

- ethical orientation of the company, including values like equality, diversity, and environmental issues [16]
- a high transparency and free access to information, especially for promotion opportunities and decisions [16]
- a strict separation of professional and personal affairs, with a working atmosphere adjustable to their personal situation [16]
- a leader in form of a coach instead of former classical leadership styles, who provides necessary assistance [17]
- a respectful interaction and communication at eye level [17]
- teamwork and varied task that support the career goals of young professionals [16]
- enabling of continuous expansion of qualifications [18]

These trends result in a need for change: Companies must meet the demands of employees and market demand regarding highly individual products in increasing variety. To achieve this target and simultaneously maintain efficient production, it is necessary to design more flexible production processes [19]. This is not possible by applying technological solutions only, the need to change the organization must be taken into account as well [19].

2.2. The car factory of the future

There are several different visions about the way cars will be manufactured in future. Parts of it describe that inflexible chains of single assembly areas based on conveyer belts are avoided, instead **driverless transport systems** are used to allow a flexible material flow within the factory like Daimler Factory 56 and ARENA2036 [20]. This leads to a quick adaption in production to fluctuating demands or increasing number of variants [21]. Additionally, various types of vehicles considering their engines, equipment, etc. can be manufactured more flexible [21].

Another feature of the future factory is the increased application of **human-robot collaborations** within assembly stations including usage of more robots in one station [22]. Those robots support humans during unergonomic or physically demanding work without

replacing them. They consist of an intuitive user interface which enables assembly workers to easily program, maintain, and repair robots themselves – no expert is needed for those services. This collaboration can therefore be described as maximally flexible and cost-effective. [23] [24]

Considering the supply of materials, the factory of the future expands with driverless transport devices and shopping carts as needed instead of supplying according to provision plans [21]. Furthermore, **smart devices** such as smart watches and tablets, provide employees on an ad-hoc basis and location-independent with necessary information like installation instructions for instance [21]. Those devices additionally show a significant benefit for teach-in phases as well as for trainings [25]. Future factories infrastructure is based on 5G network, so all humans and devices are connected with each other in the factory of the future [26]. This set-up favors the following:

- The prevention of machine or device failures [21]
- The implementation of last-minute changes by the customers [21]
- The communication of machines and the optimization of processes [21]
- The connection with suppliers and customers [24]

Moreover, the performance of a digital twin enables the employees in the factory of the future to test assembly lines before changing them physically. Additionally, the digital twin can be used to optimize the working area in combination with Virtual Reality (VR). [21] [27]

Artificial Intelligence (AI), that analyses big data can detect problems preventively within the assembly line like bottle necks or failures. Finally, every employee in the factory of the future represents a quality manager. They constantly receive information about potentials to optimize and will be supported by technology preventing any mistakes. [21] [24]

In regard of the demands of employees, global trends and the technical vision of the future factory, the industrial production faces a huge number of diverse strategic requirements. Those especially affect the automobile industry. There are assumptions on how to develop the organization of work in such a future factory but so far literature shows deficits in scientifically substantiated answers in this research area. Therefore, the question how an approach for an agile shopfloor organization design in the automotive Industry 4.0 manufacturing context can look like needs to be answered.

3. Design of an approach for an organizational concept for future car factories

The literature review has shown that there are certain strategic requirements. To develop an organizational approach considering these requirements and the demands of the future factory a transfer into organizational criteria was performed within the joint research project that is shown in the following paragraph. In the next step, several organizational forms and working methods that have been applied successfully in the present were examined to deduct the respective organizational characteristics. Those results were subsequently gathered within an approach for an organizational design.

3.1. Transferring strategic requirements into organizational criteria

In addition to the criteria a definition of their level of peculiarities is needed, to face the technological challenges as well as the requirements of the employees, and customers in the market. In order to fulfill the request of a diverse product range and customization, a quick adaption of product portfolios is required. Quick reaction times within the company depend on the time for **decision making** which needs to be short in the organization of the future.

Moreover, it is required to adapt the infrastructure of the company to react to changes quickly. An innovative organizational culture can favor the objective to restructure quickly. With the criteria **flexibility**, those characteristics can be described suitable. Being highly flexible represents a highly resilient company.

In regard of flexibility, the democratic and social change, strongly requires flexible working hours, a clear division of profession and leisure as well as an attractive work environment. This desire of current and future employees will be described by **self-determination** which should be high within a future company. In addition, the claim of new generations like Gen Y and Z to communicate on equal terms needs to be focused in the future organization form.

The same applies to the level of feedback and attentiveness, which relates to the style of **leadership** the employees wish to have. Shifting between participative and directive, managers of the future should rather lead in a participative way and communicate with employees at eye level than execute a directive leadership style. Equally significant is the transparency of information for prospective employees. This can give access to the value-orientation of the company but also within the company transparency plays an important role especially when considering promotion opportunities, which should be competence based.

However, besides the claims of the employees, there is also the demand of assistance or production planning systems that require an unlimited flow of information. Therefore, a high level of **transparency** represents an essential criteria for the organization of the future.

Finally, there is the intensity and the style of communication, which can be controlled by the reaction time but also by the **team size** in the organization which should be small in the organization of the future. All of these six criteria influence the attractiveness of a working environment and need to have a specific level peculiarity:

- Quick decision making
- High flexibility
- High self-determination
- Participative leadership
- High transparency
- Small team size

3.2. Deduction of organizational characteristics

Within the joint research project, several organizational models and innovation working approaches have been examined in detail. Currently there is no corresponding organizational form developed which fits all of the aspects of automotive shopfloor visions. The research evinced that there are seven organizational forms and working methods, whose features showed potentials to be used in the future: Scrum, Kanban, Sociocracy, Holacracy, Swarm Organization, Fractal Organization and Amoeba Organization. After developing the organizational criteria, the given working methods and organizational forms were checked for the fulfillment of respective organizational requirements. Table 1 shows them as well as potential methods including their possible way of implementation.

Table 1. Organizational requirements.

Organizational requirements	Approach	Possible implementation
Short reaction time	Scrum	Quick decision making with small teams
		Flat hierarchies and high communication intensity
	Sociocracy	Decision making by consent
		Double linking between teams
		Greater interaction and consideration of interests
Resource efficiency	Scrum	Paper-free due to digital visualization
	Future vision	Process optimization and prototype construction without employing resources via digital twin simulation
Qualification and training	Fractal Organization	Defined working time for training and development
		Know-how transfer among employees
	Future vision	Qualification as a grey collar worker
Information transparency, value orientation	Sociocracy	Decision making by consent
		Double linking between teams
		Greater interaction and consideration of interests
Clear division between profession and leisure, flexible working time	All	Self determination
		Freedom of decision-making
		Empowerment
	Fractal	5% of working time for Continuous-Improvement-Process projects (CIP-projects)
Feedback and attentiveness, communication at eye level	Scrum	Feedback culture
		Cyclical retrospective with shift planning
	Future vision	Shift planning via a smartphone application
	Scrum, Amoeba	Team leader coaches, organizes and introduces training and professional development
Flexible working hours	Future vision	Shift planning via a smartphone application
Competence-based promotion opportunities	Amoeba, Swarm	Democratic elections of the leader or coach
Team work	Sociocracy	Decision making by consent
		Double linking between teams
		Greater interaction and consideration of interests
Varied tasks, attractiveness of work	Fractal	5% of working time for CIP-projects
	All	Self determination
		Freedom of decision-making
		Empowerment
	Future vision	Shift planning via a smartphone application

After analyzing existing organizational forms and working approaches, the key elements for the organizational concept of the future company were derived and will be presented in the following.

3.3. Key elements of the organizational concept for future car manufacturer

As a result, Figure 1 shows the core elements of an approach for an organizational design, that have been abstracted in the previous chapter. In contrast to them the technical aspects of vision for future manufacturing are visualized on the left side.

Considering the structure, teams ideally consist of less than six people. They are using a principle of sociocracy that is called decision making by consent. It enables the teams to make a defined range of decisions with the participation of all members instead of top-

down. Due to that agreement a source of employee motivation is developed, and everyone can argue for his or her interests. Simultaneously, those small teams ensure that discussions do not get out of hand. Possible types of decisions made by teams on shopfloor level are not strategical or do have high impact on finance performance. Instead, competences will be used efficiently to make mostly operational decisions regarding the processes the teams are accountable for. This includes administrative issues like the digital shift planning process, the design of work stages within the teams' responsible area, decisions regarding the participation in projects, the processing of orders and the planning of changeover scenarios. The organizational approach entails the circumstance that the team manager is freed of some of his duties. This additional capacity can be used to provide assistance and support where individually necessary. In the role of a coach, the main goals will be the empowerment of employees. The concept furthermore includes, that this type of leader is elected by democratic principles, ensuring that competence is the key for a promotion. This procedure should be transparent and a motivation for employees to be familiar with the possibilities they have.

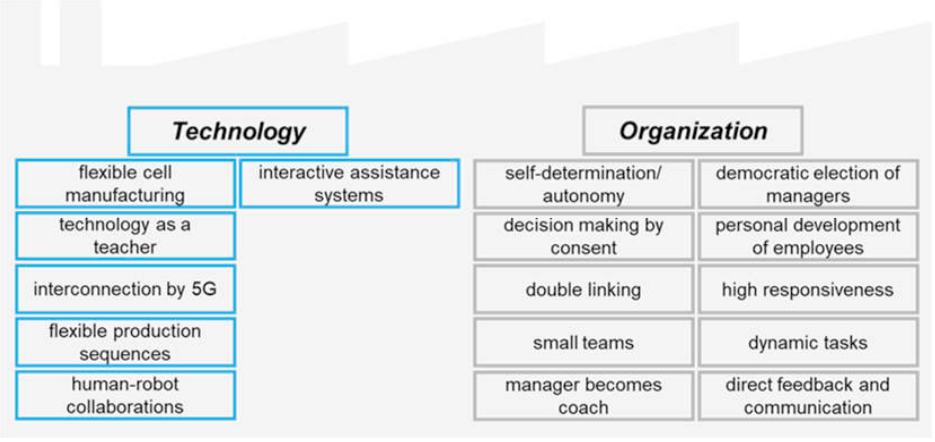

Fig. 1: Core elements of the organizational concept for the future production

3.4. Framework of the organizational concept

As mentioned before, there are major changes regarding the layout and the processes of the automotive manufacturing, aiming to increase flexibility and changeability. To achieve higher flexibility the organizational framework must be aligned. The concept therefore includes the possibility to work on a wider range of workstations and tasks than employees nowadays do. Thus, the employees' qualification plays an important role and must be enabled by technology, that is easy to understand and can be learned very quickly by everyone. The vision is to teach the entire knowledge of operating a machine or a specific tool within a very short time within the work process. This learning process is performed digitally, for instance integrated in the software of a machine but not only technological measures are responsible for the employees' high qualification levels. The organizational concept includes defined time slots to spend on qualification. However, those time slots are not fixed but can be used in a flexible and digitally supported way, which is extremely useful for a worker, for instance when there is no order to fulfill. Moreover, the learning content can be chosen by the employees themselves, depending on their daily work or the projects they are executing. Those projects are mostly related to continual improvement processes (CIP) and amount up to 5% of the employees' total working hours. Besides this opportunity, employees are forced to acquire deeper insights into their working environment. It is one of the major ideas of this organizational approach, to evolve a part of the employees into so called grey collar workers. There is a quite specific demand related to human-robot collaboration. To make sure the production is as flexible as it can be, shopfloor teams will be put into the position to program a robot, solve its issues and take care for the most part of service and maintenance work. This means that less experts like engineers, computer scientists or specialized staff are required. In case of problems this concept enables teams to help themselves faster than ever before. Waiting time for experts to arrive or being available will no longer occur.

Taking the shift planning into account, this process is understood to be digitalized in the future. Due to the variety in demand of products and self-determination of employees, accessing an IT tool to book a free spot in a certain shift and work station is beneficial for both employees and employer. This platform is very easy to use and can be accessed by smartphones or central smartboards within the manufacturing. At best, all work stations in every shift are booked in advance. Otherwise, at a defined deadline there will be a discussion in the team following the principles already mentioned to solve the problem by finding someone supporting the incomplete

work station or shift. Those discussions take place in meetings adopted from the working method Scrum. There will be relatively short and focused daily team meetings, which are designed to share relevant information, discuss or make decisions, as well as to solve escalations of the shift planning and other administrative tasks. Another adopted meeting from Scrum is the retrospective. In this organizational approach, the organization is very oriented towards feedback and communication. The atmosphere among team members will be very good and open minded. Retrospective meetings are used to reflect the teams' mood and performance, which is also essential to do better next time. The coach in the leading function also participates, supports the team members during discussions, pays attention to the target orientation of this meeting and reminds the team members of the jointly defined rules.

3.5. Resulting organizational design: TEAM

Several aspects about the factory of the future have been mentioned and considered so far. It is the strong network that is especially important within the smart factory to allow a greater flexibility in daily business. Thus, everything needs to be connected: humans, objects, machines, systems to manage customer orders, suppliers etc. The aspect that is very important to the organizational approach, however, is the fact that employees are connected as well. They are able to view the entire flow of information using devices like smart glasses or smart watches. Owning deeper insight and greater competencies, they are capable to decide autonomously as stated out before.

Visualizing the most important functional mechanisms Figure 2 presents the pillars of the organizational approach, which is called TEAM and stands for Team, Efficiency, Agility and Manufacturing. Those functional mechanisms have been deduced in three consecutive steps. First, well-known organizational forms and working methods have been analyzed by using the specific criteria that have been defined in the beginning of the research process. Second, key learnings regarding possible organizational components of the concept have been put into a practical context by including technical aspects as shown in Figure 1. Third, the holistic perspective has been enhanced by giving some examples of the resulting effects considering the integration in a manufacturing environment in the previous chapter. As a result, TEAM is designed to be the integrating element and therefore aggregates the main points of the derivation.

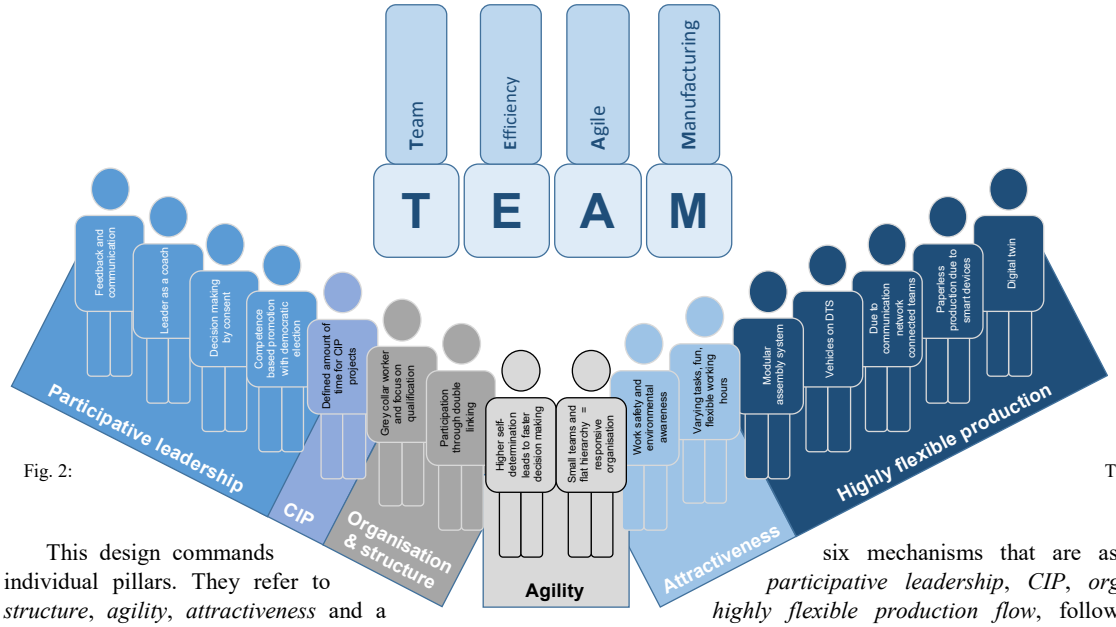

Fig. 2: TEAM

This design commands six mechanisms that are assigned to the individual pillars. They refer to *participative leadership*, *CIP*, *organization and structure*, *agility*, *attractiveness* and a *highly flexible production flow*, following the main characteristics of the organizational approach. The purpose of these mechanisms will be explained shortly in the following:

- **Participative leadership:** Starting from the left side of Figure 2 this pillar is based on occupational safety and environmental awareness, feedback and communication, a team leader as coach, decision making by consent and competence-based promotions by democratic elections. Decision-making is quick and less sluggish than in classic organizations with almost exclusively top-down decisions. In the future, all of them, the employees who benefit from new competencies for decision making, as well as the leader in its new role as a coach, contribute actively.

- **CIP:** The second pillar is based on fixed time slots for CIP projects. The continuous improvement will be a fixed component and a shared self-conception. There are no limitations to the elimination of waste like in Lean Management, but all kinds of optimizations are allowed instead.

- **Organization and structure:** The third pillar is based on the qualification of grey-collar workers and participation by double linking. As mentioned before, a team ideally consist of less than six people who are able to complete a bigger range of tasks than before. They constantly educate and qualify themselves to manage tasks which were originally performed by engineers. Considering the organization and structure it is especially important, that the organizational approach offers improved flexible possibilities for the employees to develop themselves and to accomplish their tasks. Thanks to the double linking between teams of different hierarchical levels the interests of the teams on the shopfloor are strengthened and represented throughout departments.

- **Agility:** This pillar in the middle is based on a high level of self-determination which leads to quick decision-making and small teams which enable quick reaction times. The new approach enables producing highly individualized products in batch size one, and therefore requires different mechanisms than before. The key element is a great adaptability to react quickly to changes in the market.

- **Attractiveness:** The fourth pillar is based on varied tasks, fun and flexible working hours. There is the widespread situation of an employee whose everyday life is characterized by repetitive and identical tasks. Within the new approach, this situation will be quite different as it is much more attractive on the labor market and will evoke motivated employees. Those, however, are required for a wide range of challenging tasks.

- **Highly flexible production flow:** The final pillar on the very right side of Figure 2 is based on modular assembly system, vehicles on driverless transportation systems, connected teams due to a communication network, paperless production due to smart devices and a digital twin. It respects the expected changes in the automobile market which were considered in the organizational concept also by the technological foundation. Modular and highly adaptable production landscapes which differentiate themselves technically from a traditional assembly line are used. They show a network of work stations, in which the vehicles and material are transported on driverless transportation systems.

4. Conclusion

Based on the analyses performed within the joint research project six functional mechanisms were identified which are essential to the organizational concept of the future. Those are defined in an operational design called TEAM, which considers *participative leadership*, *CIP, organization and structure*, *agility*, *attractiveness* and a *highly flexible production flow*. Furthermore, six criteria were deducted that characterize an agile shopfloor organization. Those required criteria are a *small team size*, a *quick decision making*, a *participative leadership* as well as a *high level of transparency, flexibility and self-determination*.

These aspects answer the question how an approach for an agile shopfloor organization design in the automotive Industry 4.0 manufacturing context can look like. A validation has been performed with two experts but needs to be executed in large scale to examine the research results to their degree of feasibility in the next step. Another aspect that needs to be considered is that the technological basis of this organizational approach is not definite. There are a lot of different automotive brands and not all of them are going to increase their product variety. For instance, the German brand BMW is even thinking about decreasing their product variety by up to 80% [28]. Further developments will show if this approach is going to be sustainable and can handle future challenges.

Considering all these factors the degree to which this operational design can be adopted by a manufacturing company must be researched further as the practical implementation of the concept strongly depends on the specific needs and existing structures of a company. The operational design TEAM was only developed for a model company. It needs to be examined further, whether all its functional mechanism can be implemented in the way the research project defined them.

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