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Research Article

Usefulness of digital tools when designing human robot collaboration layouts

Kerstin Johansen[1]*, Sten Grahn[2,3]

[1]School of Engineering, Jönköping University – JU, Jönköping, Sweden
[2]Mälardalen University – MDU, Eskilstuna, Sweden
[3]Research Institute of Sweden AB – Rise, Sweden

Abstract

The introduction of Human-Robot Collaboration assembly (HRC) adds complexity when designing layouts, as e.g. new safety and security issues need to be considered. In this paper, the usefulness of digital tools, such as simulation and emulation tools, to support the transdisciplinary activities in an integrated product and production development process for HRC layouts, is explored. The empirical findings was collected through interactive workshops between industrial experts and researchers, developing and analyzing challenges and needs while using digital tools. The conclusions indicate a need for an understanding of the cost drivers when utilizing digital tools, and how the reuse of digital models and knowledge can reduce development time and cost. This includes understanding of how new versions of digital tools may drive costs. Four important activities while designing a HRC layout, utilizing a digitalized production preparation process, were identified. It was also found that an efficient and reliable assessment method related to different regulations and standards is needed to support the selection and use of digital tools when designing a HRC layout.

Keywords: digital tools, human-robot collaboration, production system, production preparation, industrialization, transdisciplinary engineering.

1. Introduction

Increasing market competition, increasing product variation, and increasing requirements on sustainable operations require production preparation engineers to develop ever more competitive production solutions, that also allows for efficient continuous improvements and further development during production. Accelerating technological developments, so called emerging technologies in Industry 4.0, are at the same time increasing the possibilities to meet the increasing demands on production. Here, possibilities to implement HRC solutions and taking full advantage of the rapidly increasing possibilities to utilize ever more advanced digital tools during the production development process are identified. Meeting ever increasing demands on production by utilizing ever more advanced digital tools, efficiently, is, however, a challenge for production preparation engineers, and it is relevant to analyze how this affects the capabilities as well as possibilities to design HRC layouts efficiently by the utilization of different digital tools, such as simulation, emulation, and visualization tools.

The integrated use of digital tools must consider several performance metrics such as cost, flexibility, standardization, and efficiency, during a product realization process (Brunoe et al., 2020), where production development is one important activity (Salim, 2021). Increasing assembly volumes of customized products, which often requires manual assembly and many operators, is an industrial trend which require efficient development of systems for high mix, low volume production (Johansen et al., 2021). This often results in challenges to secure efficient ergonomic, takt time, production cost, final product diversity, productivity, and material supply solutions. The automotive assembly lines industry, which often has cycle times typically in the range of 60 to 90 seconds (Battini et al., 2012), with a Mixed Model Assembly line production planning (Boysen et al., 2009) – where each product can be unique, adds further complexity when attempting to identify optimal layout design.

Design for Automated Assembly is an approach (Synnes & Welo, 2015) that link product development, production preparation, and production development perspectives, with the purpose of handling some of the assembly challenges. The automotive assembly challenges make it relevant to analyze the possibility to design solutions where humans and robots can collaborate when assembling products designed for assembly (DfA). This analysis should include solutions for assembly manufacturing process planning, that reduce the number of operator mistakes (Genta et al., 2018). When analyzing how to plan a manufacturing process, how to assemble, what to automate, etc, there are several different types of digital tools on the market to consider, such as simulation, visualization, and emulation tools. Other tools are

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***Corresponding author:** Kerstin Johansen. E-mail: kerstin.johansen@ju.se

e.g., digital twins, cyber-physical systems, and digital shadows, which often are grouped within Industry4.0 and can be seen as part of the smart manufacturing paradigm (Thoben et al., 2017).

The emerging possibilities to design production layouts where the operator and a robot collaboratively share a task, add further challenges for production preparation engineers during the production development process, such as complexity related to safe interaction and ensured IT-security, including all 'traditional' parameters to analyze when optimizing a working environment (Gopinath & Johansen, 2019). With ever more powerful digital technologies for measuring, controlling, analyzing, and coordinating resources, the possibilities for continuous improvements and optimization also increase. This indicates a possibility to respond to the industrial trend of more automated-assisted assembly for customized products by designing HRC layouts (Malik & Bilberg, 2019; Johansen et al., 2021), by increased utilization of digital tools in the production development process (Wadekar et al., 2018). Since the variety, as well as the capacity of digital tools continuously increase, it is relevant to have a holistic view of production system layout design, over time.

Lean production, as a part of the lean philosophy, is a standardized way of organizing production, which includes activities such as waste, lead time, and defects reduction, with the aim to increase quality and efficiency in the production system, contributing to the overall system performance (Jayaram et al., 2010). Shah & Ward (2007) described lean production as a multifaceted concept, difficult to measure since it is not a singular concept, as several parameters are interacting, such as waste elimination, continuous improvement, Kanban, Just-In-Time (JIT), and employee involvement. One important aspect here is continuous improvement, and in this paper our focal point for the research started with the continuous improvement part of the lean philosophy and its relation to the increased use of digital tools during production development.

It is within the above context this paper is exploring the potential of using digital simulation, emulation, and visualization tools for different HRC layout design steps during production system development. Based on this exploring, reflections related to whether the use of the digital tools while designing HRC layouts, improves the design process, are presented. This is a contribution to research as few earlier studies have analyzed how the use of digital tools can improve the HRC layout design process, in practice.

2. Problem definition

The production engineers responsible for the development of production systems are often utilizing the same Computer Aided Design (CAD) models as the product developers, and interact in shared virtual environments (Gedell et al., 2011) in the different phases during a product realization process (Gedell et al., 2011; Johansen & Öhrwall Rönnbäck, 2021), where in some activities different technology solutions providers (Johansen & Öhrwall Rönnbäck, 2021) also are integrated into the project team.

While designing a HRC layout the dynamic challenges are to be considered, such as the movement of a robot arm, the movement of the operator, the shape of the gripper as well as the material that is in the gripper, the velocity and ergonomic issues such as lifting weight, cognitive stress from the robot and more (Gopinath & Johansen, 2016), which is a challenge when assessing risk in a virtual context (Poot & Johansen, 2018).

Within the context of increasing demands on production, increasing capacity of digital production layout design and operation tools, a sharing of the virtual environment during a production development process, and a need for an efficient and quality assured process, it was asked how useful virtual tools are as means to improve the HRC layout design process, as well as HRC cell operation, compared to an exclusively manual design process.

3. Method

From the above approach, reflecting on usefulness of digital tools in the context of production development when utilizing HRC in automotive final assembly, literature was explored from three different perspectives: (1) Impact on Key Performance Indicators (KPIs) when utilizing an HRC assembly station, (2) production preparation, and (3) virtual technologies. This was combined with an analysis of trends covering virtual support for production preparation activities in a product realization process. The emerging trends related to automated-assisted assembly was also explored.

The collaborative research with industrial partners has been ongoing in 2 research projects during a 5-year period (2016 – 2021), where interactive workshops were organized 3-4 times per year. These workshops were designed as interactive dialogues, comparable with a focus group approach (Wibeck et al., 2007), focusing on different virtual, as well as physical demonstrators and how these were designed, which contributed to knowledge how the production preparation processes for HRC layout design, could be improved. The authors interacted and participated in different workshops where virtual, as well as physical demonstrators were show-cased and discussed from different perspectives. During these workshops, 4 main questions were guiding the dialogue and reflections, with the ambition to gain knowledge and insights related to the engineering work when designing HRC layouts for assembly applications:

1. Resource allocation and skills concerning time and quality?

2. Engineering competence (expert skills) versus embedded knowledge and capability of virtual tools?
3. Compatibility between different virtual tools, risks, and aspects related to shared data?
4. Communication and information concerning different types of virtual tools?

Between the workshop sessions the demonstrators were developed by the researchers and the industrial partners. This way, the demonstrators were iteratively developed, and the outcome of each workshop contributed to the next version of the demonstrators. Furthermore, the iterative work contributed to a collaborative knowledge creation as well as knowledge sharing process, with possibilities to reuse knowledge and insights between the studied assembly cases (Bäckstrand & Powell, 2021). The three cases that has been studied were:

- Assembling flexible components on a moving line
- Assembling soft material in narrow spaces on a moving line, such as cables
- Assembling customized electronic products in a stationary assembly station incl. down-loading of software

The literature selection for this work was guided by 3 questions when analyzing papers related to production preparation and virtual tools:

1. How can different types of virtual tools contribute positively to the production development process while preparing the design of an HRC layout for an assembly task?
2. Which Resources (the digital systems, automation solutions and humans) have which role and responsibility when utilizing digital tools?
3. What different capabilities have different digital tools – visualization, emulation, simulation, or other digital tools?

4. Theoretical framework

4.1. Value and Resource parameters when designing HRC layouts

Organizations are using KPIs to follow up targets, which can be viewed as a defined set of parameters describing the Value (which is a vector of several value terms) the production system are creating by using Resources (also a vector of several resource terms). The specification of KPIs is critical for performance support when making decisions (Bishop, 2018) i.e. decisions regarding measures intended to increase created V, or reduce R. The trend towards HRC layouts increases the complexity of KPI specification, as several new value and resource terms need to be reflected upon. Our study indicates that most of the relevant KPIs are connected to (1) economical parameters, productivity, and cycle time (Malik & Bilberg, 2019), (2) throughput and utilization of equipment (Barosz et al., 2020), and (3) average assembly time (Prajapat et al, 2020). Environmental indicators are also ever more important, such as emissions and energy consumption (Paju et al., 2010; Matta et al., 2019). In an HRC layout, evaluation of the most cost-efficient layout design, where the operator and the robots can work safely together, is also important (Grahn et al., 2017). Furthermore, 'Efficient' utilization of digital tools when designing HRC layouts is defined as utilization that increases or maintains created Value, and/or decreases Resource consumption required for the Value creation, over time, i.e. increases the V/R fraction (Grahn, 2022).

4.2. Production preparation

Production preparation is an important activity in a product realization process (Gedell et al., 2011; Johansen & Öhrwall Rönnbäck, 2021). In this study the analysis of the producibility of a product is interlinked with the development of the production system (Gedell et al., 2011). Product development, production planning, and facility planning (activities included in a product realization) is possible to link through implementation and utilization of digital manufacturing software (Wöhlke & Schiller, 2005). This contributes, according to Wöhlke & Schiller (2005) to possibilities to validate both the product and the production system. For example, by using a product-oriented perspective, the assembly sequence and the accessibility can be validated station by station. Furthermore, Wöhlke & Schiller (2005) argue that ergonomic aspects, the station's layout, the use of equipment, and cycle time, can be explored in detail through process-oriented simulations. Newly developed technologies are also continuously introduced on the market, and up-skilling related to the employment of Industry 4.0 technologies such as use of innovative ICT and digital simulation is necessary (Caggiano & Teti, 2018).

The ever-increasing capability of emerging technologies require companies to keep up the skills to take full advantage of the software and/or technologies' capabilities. This includes continuous upgrading of the ability to assess the usefulness of tools, as e.g. simulation models for detailed manual operations, such as the assembly of parts and fixtures, are still of limited use (Wlazlak et al., 2019). Furthermore, production preparation is a transdisciplinary activity, where the engineers contribute to the industrialization process. The quality of the integration between the product and production development often defines the grade of success (Wlazlak et al., 2019). These transdisciplinary activities can be compared to inter-organizational relationship challenges, where three learning processes can be supportive: (1) Learning to collaborate, (2) Learning to share, and (3) Learning to create knowledge through inter-organizational collaboration (Mariotti, 2012). Here, several opportunities, as well as challenges regarding implementation and utilization of digital tools for industrialization activity support, have been identified (Safavi et al., 2021). This indicates a need to understand how to select and implement digital tools properly, including organizing implementation as well as continuous learning processes related to the tools, to secure usefulness.

4.3. Digital tools

Simulation, emulation, and visualization are different digital tools for the production preparation process. These digital tools/technologies can support decision-making for manufacturing companies (Flores-Garcia et al., 2021), with the objectives to improve the design of the production system layout, and to reduce errors. A simulation model mimics behaviors that contribute to important insights and is designed to support decisions (White & Ingalls, 2015). A simulation should show how a system or product works overtime when it is running. Further development of simulation models is, however, needed, especially discrete event simulations for new application areas (Babulak & Wang, 2008), which also is valid for HRC applications (Rao et al., 2022). Furthermore, Hibino et al. (2014) argue that it is challenging to utilize simulation for evaluation of energy consumption when designing manufacturing systems.

Visualization can be used to share specific insights about a product design in a multidisciplinary collaboration, including highlighting or filtering out different layers in a Computer Aided Design (CAD) model (Adnan et al., 2019). The library of digital tools also includes emulation, which supports production engineers when testing control systems or control code in virtual models of the product, such as programming a virtual robot, and testing it under practical conditions (Pradhan et al., 2018). This virtual support tool trend for engineering activities throughout a product realization process is demonstrated by Wagg et al. (2020), and their W model. The W model consists of two iterations, the first a virtual prototyping stage, and the second a usage of the virtual models into a digital twin supporting data and workflow analysis (Wagg et al., 2020).

To summarize, there are several types of digital tools – here we mentioned three groups – simulation, emulation, and visualization. Simulation can mimic how machinery operate in an industrial environment, using e.g. CAD models. Emulations can demonstrate the combination of hardware and software features, such as offline programming of robot movements. Visualization shows pictures or sketches without functionality.

5. Reflections from interactive workshops with industrial partners

5.1. Defining value parameters, and resource parameters

'Improvement' of the HRC layout design process during production development was given an overarching definition as: increasing 'Value' (V) creation from the HRC design process and reducing 'Resource' consumption (R) required for the Value creation, faster than before, over a relevant time frame. The desired Value from an HRC layout design process is defined as a vector of production value-'terms' created by the layout design. It is defined as the final output from the layout, e.g. terms such as 'product volume/min' and 'product quality'. Resources are defined as the utilization of a vector of Resource-'terms' (R) that are required for the created Value output. To guide the identification of how digital tools may improve the design process, resources were divided into 'HRC layout functions', e.g. 'internal HRC logistics', and 'resources required to create functions' e.g. resources required to implement, use, and upgrade 'digital tools'.

Prior to the introduction of digital tools, there are 'initial' Resources required for the HRC design process (iR). Then, at the beginning of the introduction of the digital tools, the introduction will only increase resource consumption, e.g. required for purchasing of the tools, learning, installation, and securing of upgrading solutions (dR). These 'extra' digital tool resources (dR) can, however, over a relevant time frame, be assumed to create a, possibly increased, production Value, as well as reduce the consumption of the initial resources (iR) that were used for layout design and operation prior to the introduction of digital tools, to a secondary level of consumption of the initially required design Resources (siR).

A relevant timeframe is defined as the time when the extra resources required for the utilization of the digital tools (dR) can expect a payback, i.e. when $V/_{iR} < V/(siR + dR)$. Improvement' is thus defined as an increase of the fraction V/R, over the chosen time frame. A modified 'Lean approach' was also used when it was analyzed how the V/R fraction could be increased with digital tools. We began with specification of the characteristics of the desired final HRC layout, which include ability to efficiently produce final products with sufficient quality, security, and safety. The iR resources required to secure a desired HRC layout is theoretical Analysis and Physical Tests (here called APT). With the introduction of digital tools, the resources required for analysis change, and the required physical resources for tests, operation, maintenance, and upgrading could presumably be reduced (siR).

5.2. A modified 'Lean' analysis approach

A modified 'Lean approach' was used when it was analyzed how the V/R fraction could be improved with digital tools, i.e., we began with specification of the characteristics of the desired final HRC layout, including the ability to produce final products, i.e., capacity to produce desired products (see Table 1).

Table 1. Parameters guiding analysis regarding usefulness of virtual tools for HRC layout design

Value: *Ability to produce correct:*	**Resources required for Value creation**	
	HRC functions resources	***Resources for functions***
Number of product variants	Internal HRC logistics and component flow	Analysis
Product Quality	Robot operational sequencing	Choosing digital tools
Product Volume/(Time unit)	Seamless integration of production preparation and HRC operation	Purchasing, installing, and integrating tools
Changeover time between variants	Preconditions for maintenance, product change and upgrading	Learning, and operation of tools
Traceability information quality	Product changeover and startup procedure	Maintenance and upgrading of tools
Safety and security characteristics	Solution for safety and security surveillance and control	
Accessibility	Information handling method	

The iR resources required to secure the functions and resulting Value presented in section 5.1 are theoretical Analysis and Physical Tests (APT). With the introduction of digital tools, the resources required for analysis change, and the required physical resources for tests, operation, maintenance, and upgrading is thus assumed to be reduced to siR (see Table 2).

Table 2. Resource consumption (R) required for Value creation

Activity	***iR***	***siR+dR***
Final test run	iAPT	siA + Simulations
Final robot test	iAPT	siAPT + Emulations
Final learning solution	iA	siA
Final traceability solution	iA	siA
Final change, maintenance, upgrade solutions	iA	siA
Finalized safety, security layout	iAPT	siAPT + Simulations
Finalized solution for tool integration	iA	siA
Finalized conceptual layout design	iAPT	siAPT + Visualization
Identified and specified desired V/R	iA	siA

Here, a modified 'Lean' analysis approach indicates a need for reflecting how digital tools capture a knowledge value that can be re-used in future HRC layout design processes, which may reduce set-up time and learning time. However, digital tools are known for regular new software versions, which may drive cost and extend the time needed for adopting the existing models as well.

5.3. Digital demonstrator reflections

In the workshops for the three different digital demonstrators, the authors participated with the ambition to analyze industrial reflections related to challenges and possibilities regarding digital tool use during production preparation activities. During these workshops, the following challenges summarize the overall observations from all three demonstrators:

- Challenging to identify 'improvements' when using digital tools, and how utilization contributes to improvements – especially, to quantify whether tool utilization contribute to a faster process development from idea to practical implementation;
- There is a need to secure that both the digital tools, and the competence to efficiently interact with them are in place, both from the engineering, as well as from the information user perspective;
- Digital tools need an organization that continuously maintain, upgrade, and secure relevant system functions, and user competence;
- Digital tool support decisions related to conceptual design may reduce the need to build initial physical demonstrators, which reduce cost and environmental impact related to the use of material and machines;

- The analysis of assembly tasks can be supported by digital tools, and support decisions for redesign of components and/or products, especially if the assembly is supported by a robot;
- Digital tools can be used to support analysis of a layout design and utilization of floor space before rearranging the factory, including how to design a safe HRC setting;
- Misunderstanding the difference in capability between digital tools, such as tools for visualization, emulation, and simulation, can drive cost and resource utilization in a negative way;
- Finally, digital tool software algorithms must be further developed for industrial analysis purposes, such as simulation of grippers handling soft material.

6. Usefulness of digital tools when designing HRC layouts

6.1. Transdisciplinary aspects in a guideline for digital production preparation

Virtual tools can support (Caggiano & Teti, 2018) the collaboration in the transdisciplinary production preparation process (Safavi et al., 2021), share information and knowledge between roles and needs (Adnan et al., 2019) and support creation of knowledge (Bäckstrand & Powell, 2021) through interorganizational collaboration by utilizing virtual tools in an efficient way (Wagg et al., 2020). These transdisciplinary reflections were confirmed during the industrial case observations. One example is assembly simulation of the positioning of a large system component by a robot, through a narrow space on a moving assembly line, where an operator performs the fastening while the robot holds the system component in place. For this operation it was possible to utilize geometry simulation to evaluate the positioning of the system component by the robot, securing a collision free pathway. However, a drawback was that the simulation software was not designed for analyzing the safety aspects related to the operator in collaboration with the robot on a moving assembly line. Another case observation, of a heavy component that needed to be assembled with high precision, utilizing the sensitivity in the hands of an operator, judging the friction in the assembly task, was not possible to simulate when using the simulation software. For this operation the software supported the reachability and layout planning analysis, and thereafter a physical demonstrator was built to analyze and evaluate the assembly and safety aspects.

Digital production preparation is challenging for engineers as well as for organizations, and we identified a need for a supportive guideline when digitalizing production preparation, as a decision-making support (Bishop, 2018), to improve the organizational KPIs. The KPIs need to be related to critical aspects relevant for the production development. There is also a need for support when analyzing the usefulness of which type of digital tool is applicable, when, and how it contributes to an improved V/R-fraction, especially when it is related to HRC layout design. There is also a need for reflection support regarding what Value is desired to be created from organizational, technological, as well as staff development (life-long-learning) perspectives when implementing digital tools. Table 3 present aspects to consider during a transition towards a digitalized production preparation process.

Table 3. Aspects in a guideline for digitalized production preparation (Adapted from Wadekar et al. (2018))

Areas	Needs
Organization	· Develop digital tools skills, including understanding regarding which software to use for which application or need, how to use them, and how to integrate them with the production system,
	· Managing of set-up time as well as learning curves as software tools are maintained and upgraded
Technology	· Communication interfaces between different software packages
	· Solution for continuous upgrading as well as securing back-up and traceability between versions
	· Infrastructure for digitalized, and secure support
Skills	· Continuous training to keep up with software development, and usage.
	· Agility in adapting to new interfaces and technologies.
	· Maintaining knowledge about older technologies still in use
	· Managing a continuously changing environment, wherever more information and data is available and searchable, which includes continuous training of staff to understand what to search for, when and why

6.2. Digital support for HRC layout design

The degree of interaction between humans and robots are crucial to analyze when designing a HRC layout, for safety as well as security reasons (Marvel et al., 2015), where the degrees are described as: (1) Independent – the human and the robot work separately on a workpiece without actual collaboration, (2) Synchronous – the human and the robot have a sequential task scheme, (3) Simultaneous – the human and the robot work at the same time on the same workpiece but on separate tasks, and (4) Supportive – the human and the robot work cooperatively on the same workpiece. These interaction aspects must be managed by a risk assessment procedure (see Figure 1), to identify hazards and safety risks in the HRC layout design, adhering to existing standards (Wadekar et al., 2018).

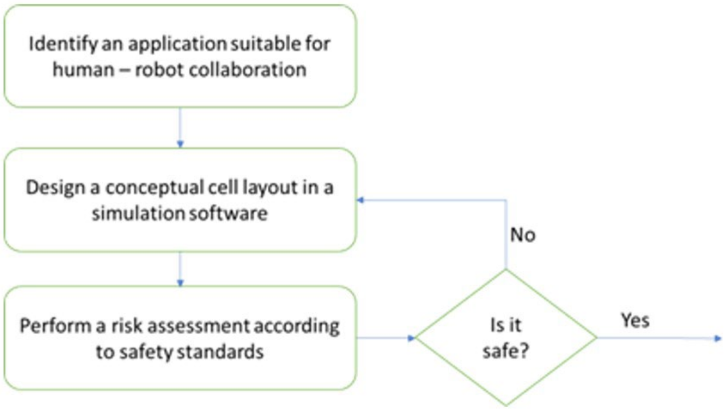

Figure 1. A generic procedure for designing a HRC layout (Adapted from Johansen & Grahn (2022)).

When designing a conceptual HRC layout, using digital tools (see Figure 1), selection of which digital tools to use is important, as safety as well as risk aspects in the HRC layout are fundamental to evaluate. This is crucial in a digital environment, as a collaborative layout where a human and a robot share a task, have a multi-dimensional challenge, with different resources moving in a working volume, with different velocities and directions. Some of these movements may also be unpredictable, especially from the humans, who e.g., can drop a handheld tool, which results in a new safety zone for the collaborative work volume. Furthermore, simulation of soft materials and its stiffness or softness that is handled by a robot gripper contributes with force feedback to the robot arm that also needs to be integrated into algorithms in a digital tool. This indicates a need for evaluation of which combination of digital tools (simulation, emulation, or visualization) will contribute to the most resource efficient Value creation ability for the organization in the conceptual design, as well as for the final layout design, i.e., which combination that creates the largest V/R fraction over time.

Understanding the capability of the different types of digital tools, is also needed, e.g. when analyzing:

- The early conceptual design phase, using a visualization software for a layout without any functionality, to get ‘a view’ of the conceptual design.
- The use of CAD for geometry simulation to analyze potential risks for collisions between the human and the robot.
- Safety sensors interaction with the movements within the cell while collaborating.
- Ergonomics of the collaborative tasks.
- The 3-D challenges within the volume where the human and the robot are collaborating.
- A flow simulation software.
- The productivity of the application when sharing a task between a human and a robot.
- Programming the robot for a safe interaction with a human.

To summarize, it is challenging to understand the level of reliability for each software when utilizing them as a support for analyzing HRC layout productivity and risks. This is important to manage, especially since the risks need to be re-evaluated if the application is changed (Grahn et al., 2017). Here, the usefulness of digital tools can differ during the lifetime of both a product and the HRC layout.

7. Discussion and conclusion

Ever more digital tools are implemented within industrial enterprises, especially as means to realize ‘Smart Manufacturing’. The intention is to improve the product realization process and increase companies’ ability to create more Value with fewer Resources, over time. However, it was found that it is not obvious that digital tools, with its cost drivers (maintenance, up-grading, learning, securing interfaces to other users of information, competence, usage, archiving of models, back-traceable models, etc.) contribute to an efficient integration into existing product realization processes. The need for a secure digitalized environment, both information control (cyber- and IT-security) and for a safe human-robot collaboration layout work environment (reliability of safety sensors and cyber-security) adds to the challenge of using ‘digitalization of the production preparation process’ to make the product realization more ‘efficient’.

The findings indicate a need for a digital tool implementation guideline that supports coordination of companies' resources (people, technology, and organization). A guideline should support selection of digital tools, and definition of interfaces between digital tools, to secure timely and cost-efficient decision quality, and time-deliverables, to secure decisions that results in a practical improvement of V/R, from digital tool utilization. This needs to be linked to the overall organizational strategy and its KPIs, where the identified aspects relevant for a guideline (see Table 1) need to be reflected upon. If the strategy is to implement HRC layouts, it is important to identify activities where digital tools efficiently can support analysis related to implementation of new emerging technologies. It is important to understand why a software is chosen and where in the production development process it is planned to contribute with useful information. A production engineer needs to understand what the digital tools should contribute with, e.g. understanding that:

- The digital tools are an information data base to search for information within.
- The digital tools need to receive useful information from the user that can be integrated into the software for analysis.
- The digital tools need to be selected based on the desired functionality – visualization (a sketch of an idea, production layout or similar), simulation (geometry simulation, reachability simulation, flow simulation or similar) or emulation (like off-line programming of a robot movement in RobotStudio, MotoSim or similar)

To conclude, HRC layout design that is integrated into a digitalized production preparation process need an efficient and reliable assessment method related to different regulations and standards. Here we have identified four important activities to manage while performing production preparation through utilization of digital tools:

- The transition from the digital cell designing phase to active operation in production.
- The digital design of initial concepts in combination with the re-use of models of older products and layouts.
- The human-machine-interaction – both for designing a safe HRC layout including risk assessment as well as software interaction as an operator
- The organizational solution for ensuring safety in production, and security in software support or control.

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