

Research Proposal

IMPLICATIONS ON TRANSFORMING AN ENGINEERING & MANUFACTURING DEPARTMENTS FROM 2D TO 3D DATA MODEL-BASED DEFINITION

Hanns Possu Gallego

University of Wales Trinity Saint David

MSc Industry 4.0 Advanced Manufacturing

Supervisor *Graham Howe*

Date *29 Apr 2022*

Contents	2
1. Introduction	3
2. Theoretical Background	4
3. 2D Drawings	6
4. 3D Design	8
5. Industry 4.0	9
6. Discussion	11
7. Conclusion	15
8. References	17

1. Introduction

The digitalisation of design offices and manufacturing companies is one of the main concepts of Industry 4.0 in these dates, (Lasi, Fettke et al. 2014). (Djassemi, Sena 2006) also suggests that paperless companies can reduce business costs, and the benefits on shop floors will be the increment of production, quality improvement, and short manufacturing time. It is visible that paperless companies are more based on shop floors and assembly lines, however, different analyses are showing that there is an important delay for the digitalisation from 3D models definition to the manufacturing departments, due to the used of technical (2D) drawings which in turn is working as a stopper to automatise the manufacturing process. The Model-Based Definition (MBD) step by step is becoming more used by various industries, but its implementation has not been completely accepted through the product life cycle, (Quintana, Rivest et al. 2010).

The aim of this proposal research is to find whether or not companies that do not want to introduce the MBD (model-based definition) as the unic suitable channel to deliver detailed parts to manufacturing in the coming years, would have huge difficulties to be competitiveness, and understand why this process is a better solution from a technological point of view.

In addition, (Bensaude 1922) is presenting the 2D drawing history, and (Gherghina, Tutunea et al. 2017) explains the 3D design evolution.

Keywords

Industry 4.0, paperless factory, BMS, RFID, TAG, CIM, DMU, CAD/CAM, MBD, MBI.

2. Theoretical Background

2.1 Paperless factory revolution.

It is vital to analyze paperless technology because it helps understand some of the processes used by factories in the Industry 4.0 revolution. According to (Djassemi, Sena 2006), some of the objectives of this technology are to improve: cost-effective; communication between the shop floor and BMS (business management system); the activities between sales, deliverables and suppliers. The expectations of these improvements will provide an increment in productivity and quality and reduce the manufacturing time at the same time as the waste.

2.1.1 Shift from a paper-based to a paperless factory

The introduction of the workflow (electronic sequence of tasks) systems helped reduce or avoid the way many shop floors were carrying the documents from one place to another by replacing the exchange of inventory lists, routing sheets or blueprints.

2.1.2 The shop floor traveller

The shop floor traveller is related to the documentation travelling around the different workstations. They need to be updated or corrected manually and keep tracking the reports, schedules, and quantities completed. The introduction of displays on those workstations allows the operators to be communicated in almost real-time with different departments and be ready for late changes or receive the latest information.

2.2 Enabling Technologies

The connection or technologies used on the shop floor to allow the paperless processes are driven by manufacturing execution systems, web-centric data, electronic devices and RFID (radio frequency identification).

2.2.1 Manufacturing execution system

MES (manufacturing execution systems) is the software that allows the communication between the workstations and devices and keeps the execution of different processes in real-time.

2.2.2 RFID

RFID is a system that plays a crucial point in the industry due to its different use to identify product data. Combining an emisor (tag) with the receptor through the emission of waves can locate and transmit information about a product in real-time.

2.3 Electronic cooperation

Most companies and industries enjoy using the internet or intranets to have a quick way of communication with their suppliers, customers, warehouses, and others, instead of waiting for long periods to get answers to their requests or queries. Due to the high demand, security and speed required to share the information in real-time, these networks should be functional to transfer different files, secure, and variable to accommodate additional information.

2.3.1 Web-centric data exchange

Web-centric data exchange is the software that allows companies to work through paperless documentation in the different departments. Depending on its configuration, this enables business-to-business and business-to-customer interaction across the internet environment. Managers, engineers and operators can have a big picture of the whole process and capabilities used in the company without wasting much time.

2.3.2 The virtual factory

It is the system used to create and share virtual information through the Intranet/Internet, implicit in paperless systems. This system permits the interaction with third-party software integration, giving the option of keeping everyone involved in the process from the beginning to the end updated with the latest information on the product and CAD files.

2.4 CIM environment paperless system

CIM (Computer Integrated Manufacturing) is the highest paperless system-level used for the more advanced companies. Computers and real-time sensors control manufacturing and assembly line shop floors with automation and machinery systems to provide error-free processes.

3. 2D Drawings

(Gherghina, Tutunea et al. 2017) argues that drawings existed from 30,000 to 10,000 B.C since people started drawing images on cave walls in France and Spain, and this can go further considering the primitive tools used by ancient Egyptians.

Complementary to this, and going into the Technical Drawing Science, the main principles used until today have been granted to Gaspard Monge, which employed the enormous progress done by Leonardo Da Vinci. Freehand and technical drawing methodologies were introduced into the engineering courses in two different scenarios and periods by these creators of engineering schools like Gaspard Monge (Paris 1775) and Alfredo Bensaude (Lisbon 1911).

Bensaude, as director of the Instituto Superior Tecnico (ITS), introduced Drawing as a discipline to all engineers arguing that it must be known and practised. Consequently, he wrote in his historical pedagogical notes:

Among all the difficulties, the greatest has been teaching students to draw as soon as possible; without this ability, they can't give the appropriate development to the practical applications. The difficulty comes from the great graphical skills deficiency of the students when they enroll at the Institute, (Bensaude 1922).

The standards-based used with the computer-aided design (CAD) software on these dates would not be possible without the degree of rigor of these prominent authors, (A. Z. Sampaio 2018).

Historically, in 1957 computer-aided design/computer-aided manufacturing (CAD/CAM) began to be developed with a program called Program for Numerical Tooling Operations (PRONTO) which had a graphical user interface by Hanratty. It was not until the 1970s when Ken Versprille started 3D models with NURBS, and Alan Grayer developed PADL (Part and Assembly Description Language), (Gherghina, Tutunea et al. 2017).

In the early 1960s, the American engineer Ivan Sutherland, for his doctoral thesis, created the first graphical user interface. This development set off the bases for software applications, operating systems and computer graphics (Pyfer).

4. 3D Design

Although in the 1980s, some CAD programs started, it was not until 1983 that Autodesk released AutoCAD. This program was mainly 2D, but in 1987 Pro/ENGINEER was the first CAD program based on solid geometry. From 1995 when SolidWorks was the first program working with the Windows platform, several programs started to come out like PLM, Solid Edge, Inventor, and others. Since the industries started using these CAD programs, hand drawings have become obsolete due to the cost, time and human errors and complexity of modifying and storing them. On the contrary, CAD software was giving enormous advantages like:

- Greater accuracy and precision
- Less specialised engineers due to the software only required basic knowledge
- Design and modification time was drastically reduced with better accessibility
- All necessary tools were in the software
- The efficient design reduced manufacturing time
- Accessibility and storing of the documentation were more manageable, as everything was electronically managed

Different studies showed that the reduced design time was achieved due to the improved quality of CAD models, the reuse of the existing models and geometry, and the collaboration between designers. Equally important was to see that the CAD models could be integrated into assemblies to create the digital mock-up (DMU), which would be the main point to interact with all parts of the project. This opens another exciting point where companies could save time and cost by using the DMUs to perform simulations such as thermodynamics, dynamics, kinematics, and

strength. The introduction of this new methodology allowed better visualisation of the product in all the stages to reduce errors in the design process, give the introduction to the rapid prototyping, and consequently, be more competitive in the market as a result of obtaining cheaper, faster, and better products, (Gherghina, Tutunea et al. 2017).

5. Industry 4.0

The enormous changes that companies are and have been made since the last decade by using the IT and new technologies to change the manufacturing systems and the organizational implications, it can be also named Industry 4.0.

The Industry 4.0 term can enclose many different things, but these 7 fundamental concepts will be always in there:

- Smart factory; the use of smart technologies with equipped sensors to be autonomously controlled.
- Cyber-physical System; it is a digital process where the parameters are set to identify physical deviations.
- Self Organisation; independent processes to allow consistency even with failures.
- Distribution and procurement; the use of independent channels to be used to speed the processes.
- Product development and services; new independent processes and systems will give more space to innovation, product memory and product intelligence.

- Human need; these manufacturing improvements are to supply and improve human needs.
- Social Responsibility; to get successful products with a sustainability company, it will be necessary having a good resource-efficiency management of the materials used.

Those fundamental concepts will need to be implemented by two main development drivers that will have to work together in order to reach successful results.

From one side, using the technology as one of these drivers it can be identified:

- The automatisisation of different processes and manufacturing cells, will reduce the physical work, and consequently, it will increase the automation and mechanization of various steps.
- Networking and digitalization; all the technologies used in the companies goes through the network, and these can increase the speed and efficiency of services and produced goods. In addition to opening more possibilities to new technologies like virtual reality, simulations and digital protection.
- Reducing in size; with the size reduction in many devices, this allows new improvements in terms of logistics and production.

On the other hand, the political, social and economic changes are identified:

- Reduced development periods; this is a success factor to get quicker products.
- Individualization on demand; having short development periods, gives the capacity of working with individual or personalized products.
- Flexibility; higher flexibility is required in production and product development.

- Decentralisation; to reduce or do not stop procedures unnecessarily.

Resource efficiency; sustainability and increasing the use of ecological material to reduce costs are key, (Lasi, Fettke et al. 2014).

6. Discussion

(McCullough 2022) maintains that the companies reacting early to this transition from 2D drawings to MBD (Model-Based Definition) will have a competitive advantage, due to the reduced time and cost achieved. 2D drawings are an unambiguous definition of the finished product, when 3D models are the master geometry to be manufactured. MBD products can be colour and tolerances coded, and go directly into the mold design with a CAM software already parameterised, eliminating the task for operators to re-enter critical information from drawings. With this in mind is easy to identify in this digital age, that there are two drawing weaknesses that were fundamental strengths previously:

- Drawings are read by humans; drawings are designed and read by humans, which gives margin to errors, and lacks the benefits from technology automation. The advantage achieved with CAD softwares having 3D models with full-scale, go backwards when scales are used to create the different views now.
- Drawings are a secondary representation of master data; once the 3D model has been created, the CAD software needs to create complex calculations to create views and

update them every time a modification has been made. Besides this, the dimensions and annotations are linked to those views that will also need to be updated.

Boeing has been one of the first companies using MBD, which is a requirement for all its suppliers. They are using MBD as the unique source of product definition to reduce conflicts between 2D drawings and 3D models. The CAD model should have all the annotations, GD&T (Geometric Dimensioning & Tolerancing), and everything required to be manufactured and to verify quality. This MBD process has opened the door to the MBI (Model-Based Inspection). As these new quality inspection tools can work together with MBD products now, this will close the loop on digital workflow, as quality labs won't be isolated from production and design processes anymore, (Husted 2018) .

There are implications to consider when companies are trying to change something that has been done in the same way for decades, and one of the main reasons is related to the employees. This article (Searle 2020), refers to different reasons why humans are resistant to changes:

- Fear of the unknown; move on without knowing what will happen
- The desire for control; having control of what is around
- Status quo; breaking the chain position could create an uncomfortable situation
- The triple effect; Once there is a change, what else will be changing?
- 'Old habits die hard'; people like the comfort zone

At this time, the companies working with paperless technologies do not mean that they have completely removed the document function from their processes (hybrid paperless system). Depending on the technologies adopted, papers have been eliminated or replaced by other methods. However, in many other different situations, the representation of paper is still alive through pdf, word, excel sheets and presentation files used in a technological environment (workflow processes), (Djassemi, Sena 2006) .

For this reason, it can be seen that the introduction of one or more technologies does not mean that the companies should make drastic changes immediately. Complementary to this, (Modrak, Zsifkovits et al. 2020), presents one of the processes used in Industry 4.0 to implement technological improvements. The company should have an approved strategy to follow, where the next aspects have been considered:

- Organisational; process, products, size and type, supply change, and business strategy.
- Gap; information technology, production and operations, automation and human resources, and direction and future business environment.
- Economical; benefit and productivity improvement, budgeting, and cost and risk analysis.
- Implementation; modules, timing and level.

Is there any benefit in keeping limiting new generations of engineers working only with 2D drawings? The new engineers are based and integrated into video games or virtual technologies. Consequently, there is no reason why universities and colleges can keep developing them only with an old 2D drawing system. They should make courses more attractive and interesting for current and future generations by developing and training more spatial abilities, which will help

them increase their cognitive skills that will be extremely necessary to use the 3D applications and virtual reality, (Gómez-Tone, Martin-Gutierrez et al. 2021).

While there is an Industry 4.0 revolution and many different technologies are being introduced into the manufacturing industries, there are signs showing that some processes are limiting the production, as a result of the use of not sustainable resources. For this reason, the industrial sector will change drastically its production, (Gubán, Kovács 2017).

Is a paperless company more environmentally friendly?

Equally or most important, reducing the use of paper saves trees and the energy used during its manufacturing process, and transportation from an environmental point of view. Paper also contributes to environmental pollution (sulfur and nitrogen oxides, and carbon dioxide).

Companies save money by introducing paperless workflows. Paper documents are harder to locate, store, easier to lose, and difficult to manage. There are some businesses spending around \$120 billions annually on printing forms, which become out of date quite soon, (Xiong 2021).

7. Conclusion

In the same way, as many factories have gone and are still going through many difficulties introducing processes and technological changes like paperless technologies previously mentioned, the same will happen with introducing this Model-Based Definition.

According to (El Hamdi, Abouabdellah et al. 2019), one of the main challenges to introducing changes or improvements into companies is the employees. Humans do not like changes in high percentages, and they do not present a good attitude or adaptability to the changes.

Companies should not look into paperless technologies to save or increment their profits by reducing or incrementing productivity. It is known that the world is dealing with a vast energy crisis due to different factors like rising temperatures, supply-demand disbalance and an ineffective reduction of carbon process, (Popkostova 2022).

All these difficulties and the difficulties in getting more raw materials are pushing to increase the prices in many other fields like the paper sector. (Stuart-Tarner 2022) shows that the increments that paper and printer buyers are suffering now could lead the industry to an unstable supply situation in a short period. Europe is expecting to have an increment in prices between £100 & £180 per tonne in products like white and brown kraft liner, paperboard and graphic papers.

Companies which keep delaying the introduction of paperless technology into their manufacturing and assembly processes will have minor difficulties having competitive prices and products in the market. This is because the 2D drawing process is more prolonged and a waste of

time when all those resources can be focused on different areas to reduce costs and the timeline of the final products.

Although human resources still play an important role in the Industry 4.0 revolution, it is noticeable that the limitations and human errors are still there. For this reason, those companies refusing modernization and development will lose around 20-30% of intelligent production, against the ones that are incorporating these new technologies, (Gubán, Kovács 2017).

8. References

A. Z. SAMPAIO, 2018. Historical Evolution of Technical Drawing in Engineering, - 2018 3rd International Conference of the Portuguese Society for Engineering Education (CISPEE) 2018, pp. 1-9.

BENSAUDE, A., 1922. Historical-pedagogical notes about the Instituto Superior Técnico. 1922 Lisbon, .

DJASSEMI, M. and SENA, J.A., 2006. The paperless Factory: A review of issues and technologies. *International Journal of Computer Science and Network Security*, **6**(12), pp. 185.

EL HAMDI, S., ABOUABDELLAH, A. and OUDANI, M., 2019. Industry 4.0: fundamentals and main challenges, 2019 International Colloquium on Logistics and Supply Chain Management (LOGISTIQUA) 2019, IEEE, pp. 1-5.

GHERGHINA, G., TUTUNEA, D. and POPA, D., 2017. EVOLUTION IN TECHNICAL DRAWING FOR MECHANICAL PRODUCTS. *Journal of Industrial Design and Engineering Graphics*, **12**(1), pp. 105.

GÓMEZ-TONE, H.C., MARTIN-GUTIERREZ, J., BUSTAMANTE-ESCAPA, J. and BUSTAMANTE-ESCAPA, P., 2021. Spatial Skills and Perceptions of Space: Representing 2D Drawings as 3D Drawings inside Immersive Virtual Reality. *Applied sciences*, **11**(4), pp. 1475.

GUBÁN, M. and KOVÁCS, G., 2017. INDUSTRY 4.0 CONCEPTION. *Acta Technica Corviniensis - Bulletin of Engineering*, **10**(1), pp. 111-114.

HUSTED, E., 2018. Model-Based Definition Puts GD&T Data to Work. *Quality*, **57**(3), pp. 25-29.

LASI, H., FETTKE, P., KEMPER, H., FELD, T. and HOFFMANN, M., 2014. Industry 4.0. *Business & Information Systems Engineering*, **6**(4), pp. 239-242.

MCCULLOUGH, B.D., 2022. Testing Econometric Software. *Palgrave Handbook of Econometrics*. London: Palgrave Macmillan UK, pp. 1293-1320.

MODRAK, V., ZSIFKOVITS, H. and MATT, D.T., 2020. *Industry 4.0 for SMEs : Challenges, Opportunities and Requirements*. Cham, Switzerland: Springer International Publishing.

POPKOSTOVA, Y., 28/01/, 2022-last update, Energy Crisis. Available: <https://www.iss.europa.eu/content/europes-energy-crisis-conundrum> [30/04/, 2022].

PYFER, J., , Sketchpad computer program. Available:
<https://www.britannica.com/technology/Sketchpad> [01/05/, 2022].

QUINTANA, V., RIVEST, L., PELLERIN, R., VENNE, F. and KHEDDOUCI, F., 2010. Will Model-based Definition replace engineering drawings throughout the product lifecycle? A global perspective from aerospace industry. *Computers in industry*, **61**(5), pp. 497-508.

SEARLE, S., 27 September, 2020-last update, IN THE FACE OF CHANGE: 5 primary reasons for people's resistance. Available:
<https://www.themindfulword.org/2020/humans-against-change/> [01/05/, 2022].

STUART-TARNER, R., 17 March, 2022-last update, More paper price increases flagged up. Available: <https://www.printweek.com/news/article/more-paper-price-increases-flagged-up> [30/04/, 2022].

XIONG, E., May 01, 2021-last update, The Sustainable Impact Of A Paperless Office. Available: <https://www.forbes.com/sites/forbestechcouncil/2021/05/11/the-sustainable-impact-of-a-paperless-office/?sh=712dbf210954> [02/05/, 2022].