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Digital Twin – A Tool for Project Management in Manufacturing

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Abstract

The Digital Twin concept has the potential to be a useful tool in project management and in Lean manufacturing. The common goal of risk management by project managers and mitigating unpredictable behavior using the Digital Twin can improve the development of manufacturing systems. Digital Twins would also aid project managers in managing resources and communication between stakeholders. The researcher is working with a manufacturing SME in the engineering sector in the application of digitalisation tools to optimize production operations. A Digital Twin is being developed, and this will be used to investigate aspects of risk and resource management as well as the benefits of communication using visualization. Are there aspects of process development that can now be measured using Digital Twins that we were not capable of previously? The Digital Twin as a central point of reference for information about a manufacturing process and its associated equipment could add efficiencies to maintenance and process improvements over the lifecycle of a system.

Keywords: Digital Twin; Project Management; Visualization;

1. Introduction

The project manager leading the development of a plating line for metal parts in a local company understands all the components the manufacturing process needs, however, in his own words, he has “no clear vision” of how the overall process will look like when implemented. The researcher is applying digitalisation tools to optimise the development of the plating line. The goal of this project is to develop a Digital Twin (DT) of the plating line and all ancillary processes. As the Plating line is in the construction phase, a Digital model is being developed with the intention of adding data communication to create a true Digital Twin.

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DT as part of Industry 4.0 is a recent development in the Digitalisation of Manufacturing. It has been described as a virtual version of a physical model. The physical model could be a car, a rocket, production equipment. Visual Components software (VC) will be used in this project. The intention is to investigate any unpredicted behaviours in the development process and see whether these behaviours can be mitigated with the use of the DT. We will also look to see how this relates to aspects of project management and Lean manufacturing. It is believed here that there are commonalities between Project Management and the DT concept. In addition, it is hoped that the definition of a DT can be improved by comparison with SCADA and other current manufacturing technologies. Reasons for using a DT will be investigated as part of a literature review and proposals for future use and development will be outlined.

2. Manufacturing

In the context of DT, we need to look at some core aspects of manufacturing. Manufacturing is a process, "In manufacturing, material flows through processes, which are executed using resources, to change the material to a higher value" [1]. We take material and do some action on it to change it into the required product. This could be building a car. We add metal, plastic, copper and all the other materials to have a car roll out of a production line. Manufacturing requires careful planning of multiple processes that come together to make the product. Project management is used in the development of a manufacturing process.

2.1. Project management

Project management is “a temporary endeavour undertaken to create a unique product, service, or result” [2]. If we build a manufacturing process, there will be some level of project management involved, even in small processes and certainly in large complex systems. The role of the project manager is to ensure that all work is completed on time, within budget and scope, and at the correct performance level [2]. There are five main elements of a project. They are the project task, stakeholders, the project environment, resources and project management [3]. Project management includes the establishment of collaboration with the parties’ involved and effective communication. This communication is aimed at developing an appropriate culture and behaviour to deliver the project [3]. The resources aspect of Project Management is where any project calls for competencies, i.e., the knowledge and expertise of individuals, groups, and organisations, as well as information that may be provided. Any project will also require financing [3]. Another core function of a project manager is risk management. It is the systematic process of identifying, quantifying, analysing, and responding to project risk. A project manager seeks to minimise project risks and is an extremely important aspect of project management [2].

In the construction industry, a new design methodology, BIM (Building Information Modelling), has been developed [4]. BIM is used in the construction phase of a project as shown in **Errore. L'origine riferimento non è stata trovata.**. The term BIM defines an operational methodology that allows an accurate digital reproduction of the structure and interoperability of the various professionals involved in the design and construction of buildings and infrastructures, **Errore. L'origine riferimento non è stata trovata.**. Yue Pan, Limao Zhang [5], proposed using a combination of BIM, Internet of Things (IoT) and data mining (DM) to create a digital twin. Flamini et al proposed the integration of BIM and SCADA [4].

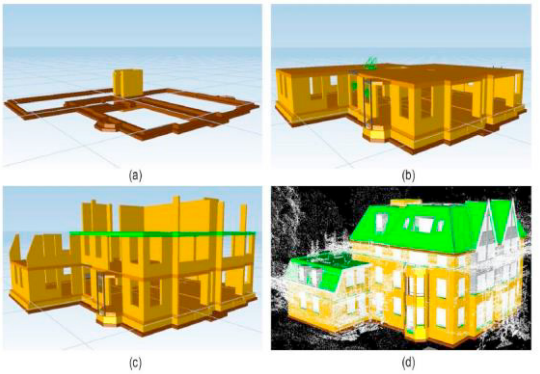

Fig. 1. 4D snapshots of the virtual model

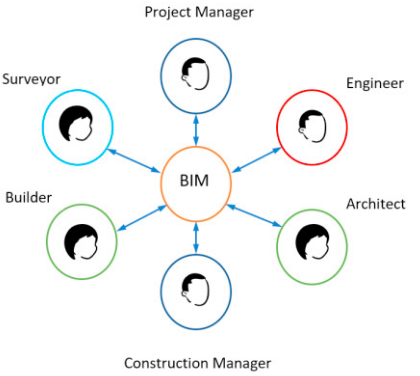

Fig. 2. BIM interoperability

VC software was selected for the development of a plating line. Digital Twins can be created using VC software [6] but it does not have the interoperability of BIM. However, to use this software, a project manager may only require a minimum amount of training to acquire project information from the Digital Twin created. This could allow the manager to quickly see the status of the project as the Digital Twin is created. The project manager could then use the DT as a visual construct to develop and share the mission, vision, goals, and objectives of the project. As production lines are rarely static over their lifetime, the manufacturing company could undertake a new project on the line with a new project manager. At this point, the Digital Twin would be in place as a tool to aid its implementation. This new project could be required due to analysis based on Lean manufacturing techniques.

2.2. Lean Manufacturing

One of the pillars of Lean is to identify and eliminate waste from a manufacturing process and an element of this is duplication. For example, why have multiple sweeping brushes in a room when there is only one person who sweeps the floor at a time. “Lean Manufacturing refers to a company’s ongoing, systematic effort to eliminate the sources of waste in a production process” [7]. The seeds of Lean manufacturing in mass production go back as early as the 18th century, when a French gunmaker, Honore Blanc, implemented the time and resource saving practice of using interchangeable parts for the assembly of guns. In the 20th century, Toyota Motor Company is generally considered to have spearheaded modern lean manufacturing by implementing (JIT) inventory system on a full scale basis in 1938 [7]. The Lean model for production and manufacturing is a collection of business practices, strategies and methods that focus on waste elimination and continuous improvement within and organisation. [8]. Lean as a manufacturing philosophy has been implemented in many industries and has evolved. Lean Six Sigma was born out of a combination of the best parts of both Toyota’s Lean production system and Motorola’s quality control system. [8].

According to Spindler et al [9], it is estimated that the overall potential of process optimisation, e.g. by use of simulation tools, is estimated to amount to up to 40%. Digital Twins are a powerful tool for real time decision support in complex manufacturing environments [9]. They are useful in Value Stream Mapping as a tool in the visualisation of information, material and lead time [10]. Value Stream Mapping is the visual documentation of the flow of material and information from beginning of the process to the customer. An example of how we can analyse the action of the operators on the plating line is shown below. Fig. 3 compares the utilisation of the two operators loading the line. Fig. 4 compares the distance travelled by each operator. It shows that the unload operator for the plating line is moving constantly. This functionality built into Visual Components software could be useful in carrying out Lean projects and process improvements.

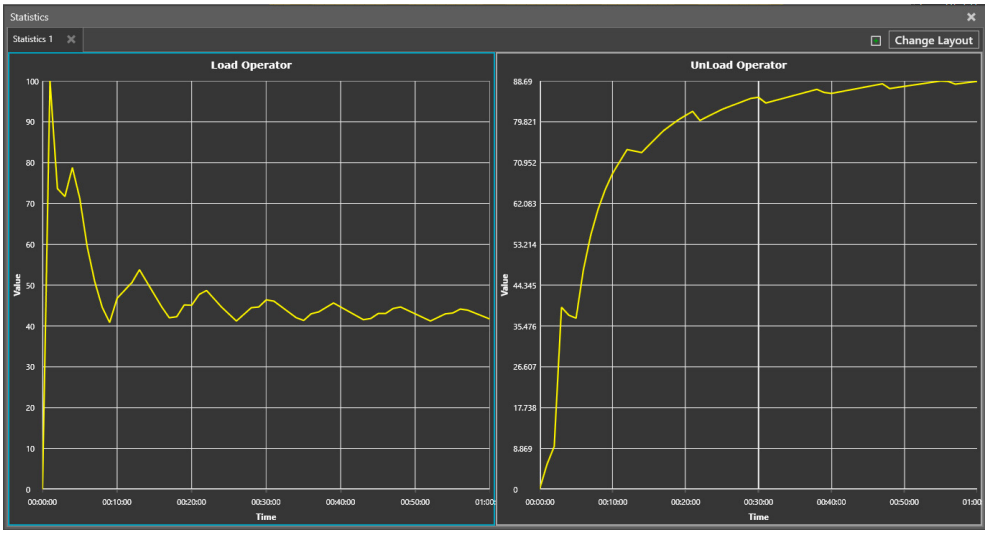

Fig. 3. Utilisation of each operator

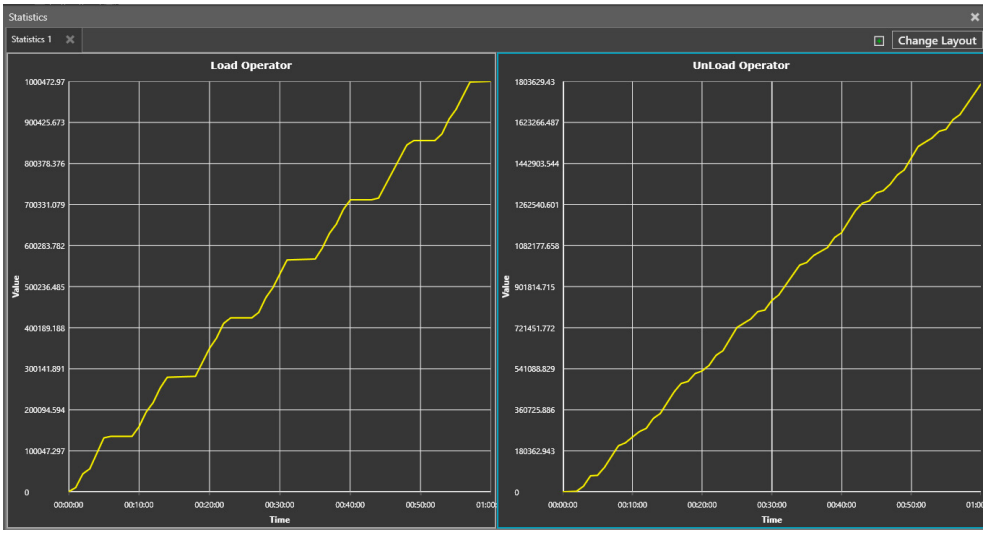

Fig. 4. Distance travelled by each operator

2.3. Digital Twin

In a paper on the DT concept, Michael Grieves outlined how a DT would exchange data with the physical model as shown in Fig. 5 [11]. The paper, Digital Twin: Mitigating Unpredictable Undesirable Emergent Behaviour in Complex Systems discusses the product life cycle and gives a definition as *"At its optimum, any information that can be obtained from a physical manufactured product can be obtained from the Digital Twin"* [11].

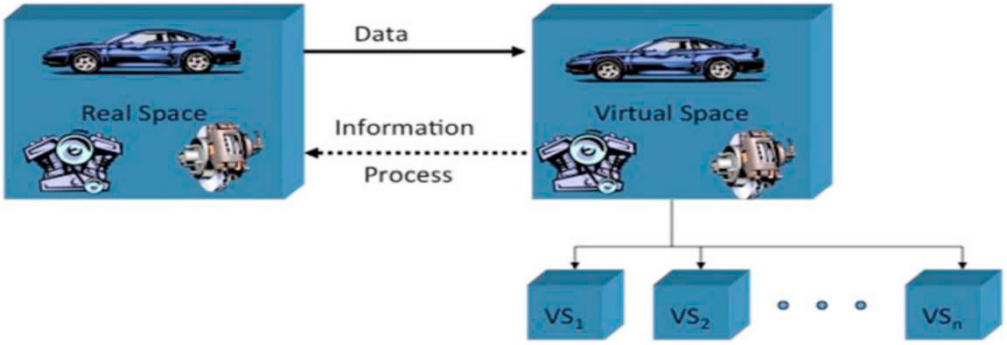

Fig. 5. Conceptual ideal for PLM

According to Kritzinger et al, in a true Digital Twin, the data flows between an existing physical object and a digital object are fully integrated in both directions [12]. In the paper, they propose three subcategories of Digital Twin:

1. Digital Model – Where there is no automated data flow between the physical and digital objects
2. Digital Shadow – There is data flow between the physical and digital object in one direction
3. Digital Twin – The data flow is fully integrated in both directions.

Using these subcategories, the plating line virtual system is a Digital Model. It is the intention to connect the VC software to the plating line using an OPC interface, which will allow it to become a Digital Shadow or Digital Twin by this definition. However, it is proposed that this definition of a true Digital Twin is too narrow. There would be some processes that are fully automated, and data could be bi-directional. However, in the example of the plating line, data could not be sent to the operators to move tables to improve product flow or other process functions. There are also validated manufacturing processes where it may not be acceptable to allow a Digital Twin to change process parameters automatically. The Digital Twin as outlined by Michael Grieves would seem to be a more practical and comprehensive definition.

In terms of lean manufacturing, we need to have a good reason to invest time and resources in what is a duplicate of a physical system. However, if we already have the physical system, what is the benefit of building a second one? Software can be expensive and there are maintenance costs. There are also the costs with employing an engineer or technician to build a DT and to maintain it over its lifetime, for example, in using a DT to manage routine maintenance of a physical system [13]. There are already software packages that can do this such as PEMAC. PEMAC software has been used to manage preventative maintenance strategies for over 30 years [14]. Another was where a DT was used in the management of Wetlands [15]. This system as outlined was similar in functionality to building management systems or SCADA (supervisory control and data acquisition). SCADA systems give real time status of a system but that is not the same as a DT [16].

As a source of information, a Digital Twin could become or contain an equipment technical file. In the machinery directive 2006/42/EC machinery, a technical file must be available [17]. Annex VII states that the technical file must demonstrate that the machinery complies with the directive. A list of information is required for the technical file such as general description, a copy of instructions, overall drawing of the machinery and drawings of the control circuits. It is envisioned in this paper, that Digital Twins could contain or reference this information and become a digital technical file. It would have an advantage of being a central point of information that can be accessed much more efficiently. Fig. 6 is a proposed model that shows communication of data and information between that physical and virtual that is multidisiplinary. Fig. 7 shows the benefits of using Digital Twins over the lifecycle of a product.

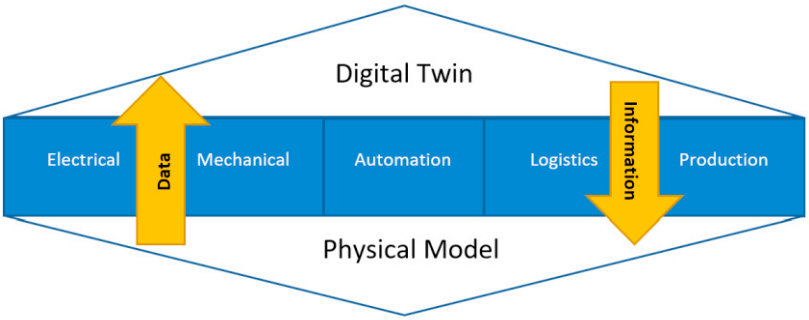

Fig. 6. Proposed Digital Twin Model

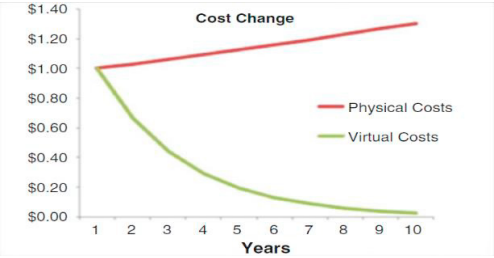

Fig. 7. Financial benefits of Digital Twin [11]

3. The Plating Line

The Plating line is shown in Fig. 8**Errore. L'origine riferimento non è stata trovata.** The intention here is to create a working DT of the line. This will be done using Visual Component Software. The basic information shown above comes from .stp files created on AutoCAD and imported into the software.

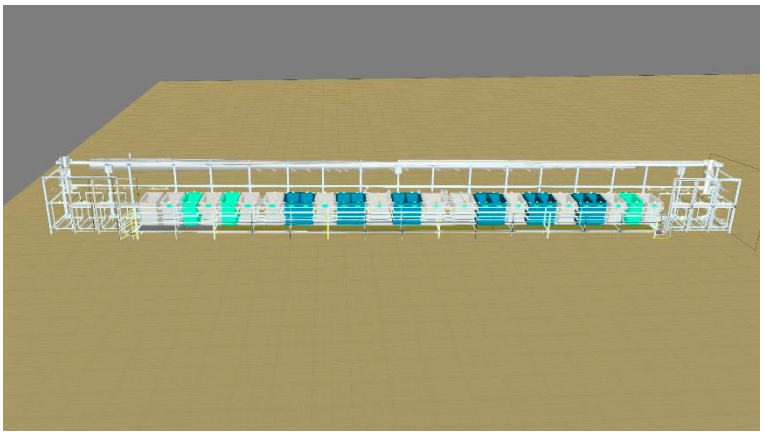

Fig. 8. The Plating Line

From here, a model will be built, and it is the intention to build all the ancillary functions that occur during production to give a realistic view of how the line operates. This will include the building the line is in, the production staff, tables, chairs, and whatever is required. Gathering all the information into one place is a core goal of this project. The

stages of building the digital model are shown below in Fig. 9, clockwise from top left. A single treatment tank was converted from the .stp file and made a component in VC. All the parts were added until the full line was completed. Finally, the floor layout with doors and walls were added. The main picture shows an operator at the line HMI (human machine interface), ready to load a trolley on the line. These trolleys are used to move parts to and from the line.

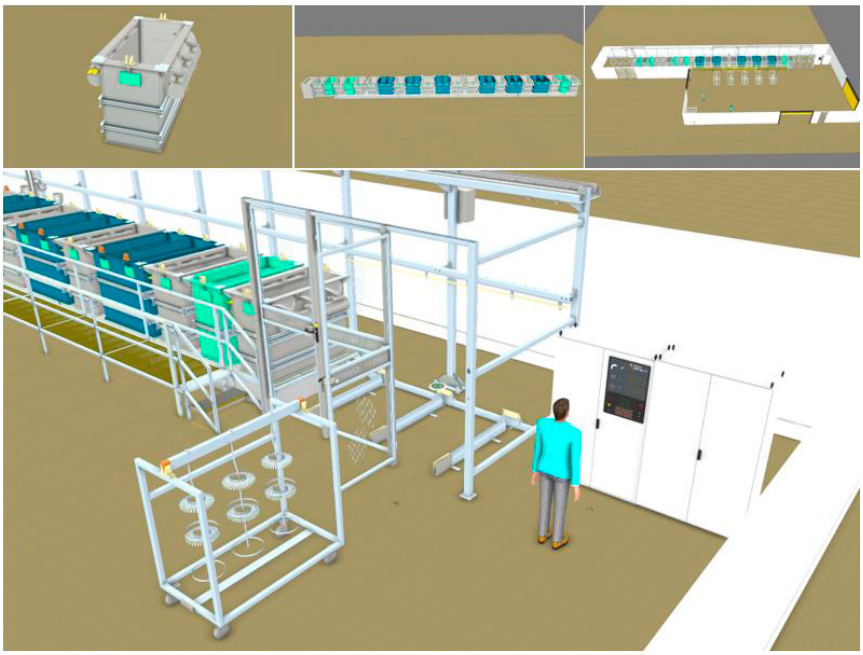

Fig. 9. Virtual Plating Line Development

4. Conclusions

The ability of a DT to show the information visually is a more efficient way of communicating available information for project managers. It is much more than a simulation of a process. It has the potential to be a central point of information to all personnel involved in building a production process, operating, and maintaining them and to use the history recorded for future development [18]. The development of a Digital Twin in addition to a physical product or process, could become a useful tool project managers and in the implementation of Lean projects for process improvements

The plating line being developed in this project is still in the create phase. It needs to be built and put into production. As such, the analysis will take some time to get a full picture of how the DT has evolved. The initial progress to date has been encouraging and all the stakeholders are engaged with the concept.

The Visual Components software used in this project is working very well to date but could be developed further. It cannot do everything such as being a mechanical and electrical design package in one, but it could allow the user to enter reference data and location of the information. It does have the ability to reference web pages, but this could be improved upon. Other software such as Delmia looks to be working in the direction of connecting people, ideas, data and solutions in a single environment [19] and a review of the different software companies providing DTs may be useful to determine the current status and trend of development.

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