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Digital Twins Technology: A Bird's Eye-View From Coimbatore Manufacturing Firms

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***Abstract*: Digital Twins (DT) is ranked top among the top 10 strategic technology trends. It symbolizes the convergence of the physical and virtual world in which every industrial product and prototypes will get a dynamic digital representation. DT is commonly known as a key enabler for the digital transformation. It is regarded as the 'Mind of a machine'. The aim of this research paper is to provide the awareness level of Coimbatore based manufacturing firms about this Digital Twin concept. Coimbatore is an industrial hub which caters to the need of global manufacturing by supplementing and supplying with adequate raw materials, spares and components.**

Keywords: Digital Twins, Data Twin Environment. Digital Twin Prototype (DTP), Digital Twin Instance (DTI), Digital Twin Aggregate (DTA), Digital Twin Environment, Manufacturing, and Physical Product.

I. INTRODUCTION

The Digital Twin (DT) is a computer based versions of anything that physically exists. It is a cloud based practical or image of our asset maintained throughout the life cycle and easily accessible at anytime. DT is a virtual copy of something real, modeled to behave in absolute reality. In digital twins, one platform brings all the experts together providing influential analysis, insight and diagnosis.

II. DIGITAL TWIN EXPLAINED

A. Meaning

The Digital Twin in its origin describes mirroring or duplicating of a product as the state-of-the-art allows the processes to be as well subjects of virtual space imitation. DT was made in the year 2002 by Michael Grieves in the framework in a presentation apprehending the Product Lifecycle Management (PLM). It is a digital informational construct about a physical system, created as an entity on its own and linked with the physical system of consideration (Werner Kritzinger et al. 2018).

B. Definitions

Glaessgen, Stargel (2012) summarizes "*the digital twin is an integrated multi-physics, multi-scale, probabilistic*

simulation of a complex product and uses the best available physical models; sensor updates etc., to mirror the life of its corresponding twin. (Tao et al. 2017)

In terms of manufacturing, (Garetti et al. 2012) defined as, "The DT consists of a virtual representation of a production system that is able to run on different simulation disciplines that is characterized by the synchronization between the virtual and real system, thanks to sensed data and connected smart devices, mathematical models and real time data elaboration. The topical role within Industry 4.0 manufacturing systems is to exploit these features to forecast and optimize the behavior of the production system at each life cycle phase in real time." (Negri et al.2017)

C. Purposes of Digital Twins

There are three purposes of Digital Twins generally opined by the industrialists (Users) and technologists (Creators). They are:

(i) Digital Twin Environment: TD is used to capture environmental data such as location, configuration, financial models etc for the digital imitation.

(ii) Predictive: DT helps in accurately predicting the current state and future of physical assets by analyzing their digital counter parts. These connected digital items generate data in real-time and helps the users in better understanding, analysis, and to predictive the problems in advance or to get early warning signals etc.

(iii) Interrogative: The data and information obtained through DT can be used for interrogations about the physical product, extrapolative, learning, and developing a new framework for further development.

D. Types of Digital Twins

The Digital Twin has been classified into three categories as follows:

(i) Digital Twin Prototype (DTP): This consists of designs, analyses, and processes to understand real, physical object or product.

(ii) Digital Twin Instance (DTI): It is the digital twin of each individual case or instance of a product or object once it is manufactured.

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(iii) Digital Twin Aggregate (DTA): It is the aggregation of the DTI and the data and information attained from DTI are used for interrogation about the physical product, prognostics, and learning. (Grieves, M and J. Vickers, 2016)

E. Digital Twins Model or Framework

As we know DT is one of the top 10 strategic technologies emerged in the market especially for the manufacturing sector, it's all start from the imagination of linking virtual images and digital elements. The Pragmatic Digital Twin model or framework is represented in the below diagram:

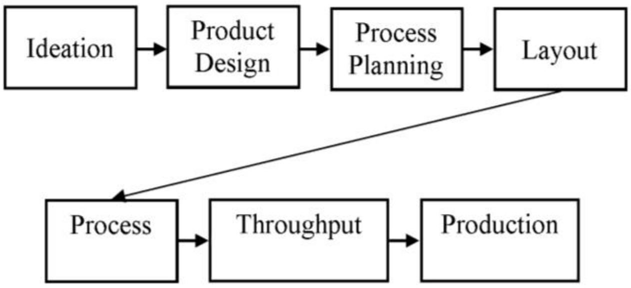

Fig. 1 Conceptual Framework of Digital Twinning Concept

III. REVIEW OF LITERATURE

This section presents the review of related conceptual papers, research publications, conference presentations, proceedings and case study reports.

Yi Cai et al (2017) presents reports pertaining to sensor data integration and information fusion to build 'digital-twins' virtual machine tools for cyber physical manufacturing. They discussed the techniques for deploying sensors to capture machine specific features, and analytical techniques of data and information fusion.

Another paper proposes a comprehensive reference model for DT, which serves as a digital twin of the physical product in design and production engineering. Important model properties namely scalability, inter-operability, expansibility, and fidelity along with Product Life Cycle (PLC) are addressed by the authors. (Benjamin Schleich et al. 2017).

Knapp et. Al (2017) proposed a building block for developing a digital twin of the AM process that will utilize a transient, three-dimensional model that calculates temperatures, velocity fields, cooling rates, solidification parameters and depository geometries. Their model is proposed and validated with the experimental data of single-pass, single-layer deposits.

The major requirement in DT is a database of temperature dependent thermo physical properties for commonly used engineering alloys and Mechanical properties that are needed at high temperatures typically for low strain rate. There are lots of issues to be overcome in order to feel the real-time benefits using DT. (T. DebRoy et al. 2017)

The analyses of research work suggest the costs of Digital Thread and Digital Twin make the concepts impractical to fully implement. The analysis indicates that software development and sustainment for Digital Thread is very expensive and the cost for Digital Twin is impressively higher. The affordability of the cost and investment in digital twins is unimaginable. Timothy & Mark (2017)

Mika Lohtander et. Al (2018) shown the main characteristics and the restriction needed to describe Micro Manufacturing Model which is used later on as an element of overall a digital twin. It consists of a machine, material; method, measurement and modeling fields like a physical world depict it.

Merging the real-time data with the simulation models from designs allows on the other side to give good forecasts based on the realistic data. These tackles the opportunities to use simulation for assist systems to support operators and planners during normal operation as well as for maintenance and service by simulation-based forecasting (Roland et al. 2015).

The skin model allows a mental model and thought or imaginary experiments to develop a theoretical inspection procedure, hence connecting the specification world to the physical world. In addition, a number of mirrored or imitative operations and uncertainties were identified (Nielsen HS, 2013).

IV. OBJECTIVES AND HYPOTHESES

This research works is done to understand the awareness level of the manufacturing firms of different sector in Coimbatore about the Digital Twins (DT). The objectives and hypotheses formulated based on the literature survey are given below.

A. Objectives

- To understand the awareness of manufacturers in Coimbatore on Digital Twin Technology,
- To study the awareness of the respondents' on DT environment or infrastructural requirement, and
- To know the awareness of the respondents' on DT cost and investment necessity.

B. Hypotheses

1. There is no significant difference between Traditional and Modern firms (Type of Firms) in the awareness of DT technology,
2. There is no significant difference in the DT Environmental Requirements based on types of firms,
3. There is no significant difference in awareness on cost & investment need awareness and the type of firms,
4. There is no significant difference between manufacturing sectors (Automotive, Motor Pumps, Paper, Textiles Engineering, Wet grinder and Home appliances) towards the awareness of DT technology,
5. There is no significant difference in the DT environmental requirements based on manufacturing sectors,
6. There is no significant difference in the cost and investment need awareness based on manufacturing sectors,

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7. There is no significant difference between the nature of manufacturing firms (Firms engaged in core production and Subsidiary units or outsourced firms) towards the awareness of DT technology,
8. There is no significant difference in the Environmental need requirement awareness based on the nature of manufacturing firms,
9. There is no significant difference in the awareness of DT cost and investment requirement and nature of manufacturing firms.

V. METHODOLOGY AND DATA ANALYSIS

Primary Data is collected in this research work to examine the level of Digital Technology awareness across Types of firms, Nature of firms and Manufacturing sector about the general awareness, DT environment requirement and Cost & Investment requirements. Data is collected using structured questionnaire and interview schedule method. Responses from 56 respondents in different manufacturing sectors are analyzed here in this section. Snowball sampling techniques is used to pick samples. Awareness on Digital Twin technology in terms of Environment Requirements and Cost – Investment Requirements is taken as the core point of research. 8 factors from Industrial profile, 11 factors in the environmental requirements and 16 items in terms of cost-investment requirements were included in the questionnaire.

A careful analysis using Cronbach's Alpha test is adopted to measure the reliability of tool as this test determines the relationship of a given set of factors. The reliability coefficient value for the tool is 0.641.

Hypothesis 1: There is no significant difference between Traditional and Modern firms (Type of Firms) in the awareness of DT technology.

Table- I: Awareness of DT Technology among types of firms

General Awareness of DT Technology across Type of Firms	*Mean Value*	*S.D*
Traditional Firms	42.75	7.292
Modern Firms	36.29	7.011
Inference: T=1.288, p=0.169 > 0.05, Hypothesis Accepted		

Source: Computed from the Survey data.

The p value is 0.169 which is greater than the level of significance 0.05. So, the null hypothesis accepted and it is concluded that there is no significant difference between Traditional and Modern Firms in the awareness of Digital Twin technologies.

Hypothesis 2: There is no significant difference in the DT Environmental Requirements based on types of firms.

- **Table- II: Awareness of DT Environmental requirements among types of firms**

Environment Requirement Awareness of DT Technology across Type of Firms	*Mean Value*	*S.D*
Traditional Firms	36.38	5.225
Modern Firms	39.55	6.118
Inference: T=2.552, p=0.016 < 0.05, Hypothesis Rejected		

Source: Computed from the Survey data.

The p value is 0.016 which is lesser than the level of significance 0.05. So, the null hypothesis is rejected and it is concluded that there is a significant difference in the DT Environmental Requirements based on types of firms.

Hypothesis 3: There is no significant difference in awareness on cost & investment need awareness and the type of firms.

Table- III: Awareness of cost-investment need awareness among types of firms

Cost-Investment need Awareness across Type of Firms	*Mean Value*	*S.D*
Traditional Firms	51.28	7.227
Modern Firms	48.61	11.221
Inference: T=2.374, p=0. 018 < 0.05, Hypothesis Rejected		

Source: Computed from the Survey data.

The p value is 0. 018, which is lesser than the level of significance 0.05. So, the null hypothesis accepted and it is concluded that there a significant difference in awareness on cost & investment need awareness and the type of firms.

Hypothesis 4: There is no significant difference between manufacturing sectors (Automotive, Motor Pumps, Paper, Textiles Engineering, Wet grinder and Home appliances) towards the awareness of DT technology.

Table- IV: Awareness DT Technology among manufacturing sectors

Environment Requirement Awareness of DT Technology among Manufacturing Sectors	*Mean Value*	*S.D*
Automotive	33.39	4.997
Motor Pump	31.33	5.055
Paper	39.22	7.011
Textile Engineering	36.89	4.626
Wet Grinder and Home Appliances	31.89	5.011
Inference: T=2.982, p=0.026 < 0.05, Hypothesis Rejected		

Source: Computed from the Survey data.

The p value is 0.026 which is lesser than the level of significance 0.05. So, the null hypothesis is rejected and hence it is concluded that there is a significant difference between manufacturing sectors (Automotive, Motor Pumps, Paper, Textiles Engineering, Wet grinder and Home appliances) towards the awareness of DT technology.

Hypothesis 5: There is no significant difference in the DT environmental requirements based on manufacturing sectors.

Table- V: Awareness of DT Environmental requirements among manufacturing sectors

Environment Requirement Awareness of DT Technology among Manufacturing Sectors	*Mean Value*	*S.D*
Automotive	42.39	3.881
Motor Pump	41.86	4.994
Paper	32.33	5.954
Textile Engineering	41.55	4.288
Wet Grinder and Home Appliances	29.33	3.335
Inference: T=2.661, p=0.031 < 0.05, Hypothesis Rejected		

Source: Computed from the Survey data.

The p value is 0.031 which is lesser than the level of significance 0.05. So, the null hypothesis is rejected and hence it is concluded that there is a significant difference in the DT environmental requirements based on manufacturing sectors.

Hypothesis 6: There is no significant difference in the cost and investment need awareness based on manufacturing sectors.

Table- VI: Awareness of cost-investment need awareness among manufacturing sectors

Cost-Investment need Awareness among manufacturing sectors	*Mean Value*	*S.D*
Automotive	28.22	2.99
Motor Pump	27.66	3.12
Paper	29.29	4.11
Textile Engineering	32.36	3.22
Wet Grinder and Home Appliances	23.44	1.99
Inference: T=1.319, p=0.190 > 0.05, Hypothesis Accepted		

Source: Computed from the Survey data.

The p value is 0.190 which is greater than the level of significance 0.05. So, the null hypothesis is accepted and hence it is concluded that there no significant difference in the cost and investment need awareness based on manufacturing sectors.

Hypothesis 7: There is no significant difference between the nature of manufacturing firms (Firms engaged in core production and Subsidiary units or outsourced firms) towards the awareness of DT technology.

Table- VII: Awareness of DT Technology among nature of firms

General Awareness of DT Technology among nature of Firms	*Mean Value*	*S.D*
Firms engaged in Core Production	53.28	7.566
Subsidiary Units or Outsourced Firms	32.33	3.17
Inference: T=2.881, p=0.056 > 0.05, Hypothesis Accepted		

Source: Computed from the Survey data.

The p value is 0.056 which is greater than the level of significance 0.05. So, the null hypothesis is accepted and hence it is concluded that there is no significant difference between the nature of manufacturing firms (Firms engaged in core production and Subsidiary units or outsourced firms) towards the awareness of DT technology.

Hypothesis 8: There is no significant difference in the Environmental need requirement awareness based on the nature of manufacturing firms.

Table- VII: Awareness of DT Environmental requirements among nature of firms

General Awareness of DT Technology among nature of Firms	*Mean Value*	*S.D*
Firms engaged in Core Production	48.49	6.554
Subsidiary Units or Outsourced Firms	42.44	4.97
Inference: T=0.891, p=0.410 > 0.05, Hypothesis Accepted		

Source: Computed from the Survey data.

The p value is 0.410 which is greater than the level of significance 0.05. So, the null hypothesis is accepted and hence it is concluded that there is no significant difference in the Environmental need requirement awareness based on the nature of manufacturing firms.

Hypothesis 9: There is no significant difference in the cost and investment need awareness based on manufacturing sectors.

Table- IX: Awareness of cost-investment need awareness among nature of firms

Cost-Investment need Awareness among nature of firms	*Mean Value*	*S.D*
Firms engaged in Core Production	59.33	7.99
Subsidiary Units or Outsourced Firms	39.38	4.55
Inference: T=1.619, p=0.077 > 0.05, Hypothesis Accepted		

Source: Computed from the Survey data.

The p value is 0.077 which is greater than the level of significance 0.05. So, the null hypothesis is accepted and hence it is concluded that there no significant difference in the cost and investment need awareness based on manufacturing sectors.

VI. RESULTS AND RECOMMENDATIONS

A. Results

It is found that there is no significant differences between Traditional and Modern Firms in the awareness of Digital Twin technologies, cost and investment need awareness based on manufacturing sectors, Environmental need requirement awareness based on the nature of manufacturing firms, the nature of manufacturing firms (Firms engaged in core production and Subsidiary units or outsourced firms) towards the awareness of DT technology, and in the cost and investment need awareness based on manufacturing sectors.

There are significant differences in significant difference in the DT Environmental Requirements based on types of firms, between manufacturing sectors (Automotive, Motor Pumps, Paper, Textiles Engineering, Wet grinder and Home appliances) towards the awareness of DT technology and DT environmental requirements among manufacturing sectors. The below table portrays the hypotheses results in a nutshell.

Hypothesis 1	Accepted
Hypothesis 2	Rejected
Hypothesis 3	Rejected
Hypothesis 4	Rejected
Hypothesis 5	Rejected
Hypothesis 6	Accepted
Hypothesis 7	Accepted
Hypothesis 8	Accepted
Hypothesis 9	Accepted

B. Recommendations for future research

The recommendations are based on the processed data and the interview with the industrial experts.

- Empirical type of research can be done
- More factors in vertical and horizontals can be done
- Study can be done by involving simulation and other latest technologies

VII. CONCLUSION

As Coimbatore is an industrial hub it is imperative to know the latest trends in manufacturing filed to cope up with changing business environment and to win business.

This is a fundamental study to know the awareness on Digital Twin Technology in manufacturing field. Amidst the awareness on DT, few manufacturers have updated information and probed into it. They stood away as there are lots of technical risks and challenges. Investment is the major concern for many industrial persons in Coimbatore as the market demand for their products and the Life Cycle of their core area are shrinking very fast and the manufacturing technologies like Digital Twins also gets faded in shorter period of time.

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