Kurdish Studies
October 2022
Volume: 10, No: 2, pp. 230-245
ISSN: 2051-4883 (Print) | ISSN 2051-4891 (Online)
www.KurdishStudies.net

Received: August 2022 Accepted: September 2022

To Identify the Hurdles and Slopes in Adoption and Implementation of Industry 4.0 Technologies in Indian Automotive Industries

Rahul Kumar Singh[1], Md. Nasir[2], Md. Imran Khan[3]

Abstract

Purpose: *This paper focuses on jotting down all the enablers and barriers for implementation of Industry 4.0 in Production planning and control. Industry 4.0 is now growing in exponential form after the pandemic phase. All industries are willing to be connected and perform their task in much faster and efficient manner which they Industries re not doing it before. This paper will keep focus on the catalysts and impediments for implementation of Industry 4.0 for production planning and control in their organization.* ***Design/Methodology/Approach:*** *To find out the list of enablers and barriers with the help of fuzzy concept. Fuzzy Delphi study is done among top decision makers and by Best Worst Method it is ranked as per their importance. This study is conducted among top auto makers with qualitative approach. This paper will also emphasize on the area where others have failed and where Industries need to focus for its implementation in their industries. This paper will use statistical approach and formulations to identify the list of critical catalysts and impediments with their priority order of ranking.* ***Findings:*** *This paper delivers the list of barriers and enablers and their ranking among themselves based on their importance of implementation. The top raked enablers are the low hanging fruits which has to be done first in order to implement Industry 4.0 in Production planning and control and the top ranked barriers are the top hurdle which will take most of your time and energy which needs to be taken care last in order to implement Industry 4.0 in Production planning and control.* ***Practical Implications:*** *This study is done among top auto makers in India which made delay in the responses and this study has taken only top auto makers as its sample space.* ***Originality/Value:*** *The results are generated from the original work done involving the senior most members from the top auto makers of the relative field.*

Keywords: *Industry 4.0, Production planning and Control, Drivers, Barriers, Impediments, Catalysts*

1. Introduction

Industries are in a new phase where they are performing in a manner and rate which they have never performed before. Their rise in stock market is remarkable. Most of these industries have crossed their 52 week high target set by themselves in quite a few months. Industries talk about Fortune 50 companies of India, which is termed as Nifty 50 in stock market. Its graph shows sudden increase after pandemic.

The above graph of Nifty 50 shows the transition phase of all the gain happened after pandemic in March 2020. After the steep fall, there is sudden increase in the market which almost gained double where it was. This situation happened when all industries showed their agility towards the change and incorporation of technology which has to be worked remotely. During this period organization started thinking in that manner which Industries have never thought before

1 Mittal School of Business (Operations), LPU- Phagwara, Punjab, India, Email: rahul_singh80@yahoo.com
2 Mittal School of Business (Operations), LPU- Phagwara, Punjab, India, Email: mohdnasir22@gmail.com
3 School of Business, UPES, Dehradun, Email: imrankhan3107@gmail.com

and being connected with the manufacturing unit remotely is the prime function of Industry 4.0 and its existence.

Figure- 01: Nifty 50 Graph.

In a way Industries can say that the pandemic has helped industries to incorporate and implement Industry 4.0 in their organization. Production planning has many activities entangled around it. Today's market is very volatile and customer driven. Customers are becoming very impatient due to the various offerings from the competitors. Having agility in manufacturing is not enough now to get sustained in this market condition. Industries need to increase our bars and get synchronised with the customer's demand and deliver them their demand before anyone could do it. Now the world needs speed in everything what Industries do and what Industries intend to do. Every person wants their problem to be resolved quickly and effectively. To cater all the demands and fulfilling them is the shortest possible time there must be a strong tool which helps the organization achieve its target. Industry 4.0 in Production planning and control will help building a tool to connect with the stake holders, suppliers & aggregate shops and give the real time information to work in a lean manner help achieve the target. The main advantage of having connected peoples will be in production planning and control, the decision making activity will be at faster rate and conversion of the relative decision on actual shop floor will be much faster than before. Staying connected will help everyone related to the decision stay up to date with their compliance to the actual work being carried out in the shop floor. Sales and Marketing can have the live data on their tips to give their valuable commitments to the customers. Parallel suppliers and vendors can get the live updated data from the parent organization. Inventory management would be add on advantage of this implementation of Industry 4.0 in Production planning and control. Working on actual levels on inventory while operation and acting upon the constraints which gets automatically detected through implementation of Industry 4.0 in Production planning and control.

Catalysts, as per google it means "a person or thing that precipitates an event". Many paper or theory in academia is termed as "Drivers". This means drivers are those components or feeling or areas which supports the implementation of the subject. Impediments, as per google it means "a hindrance or obstruction in doing something". In academia it is termed as "Barriers". This means Barriers are those components or feeling or areas which hinder or obstruct the

implementation of the subject.

As per Deloitte analysis there are total seven types of wastes which impacts business performance and in which some or the other reason for high carbon foot prints in the society are comprised of these seven wastes.

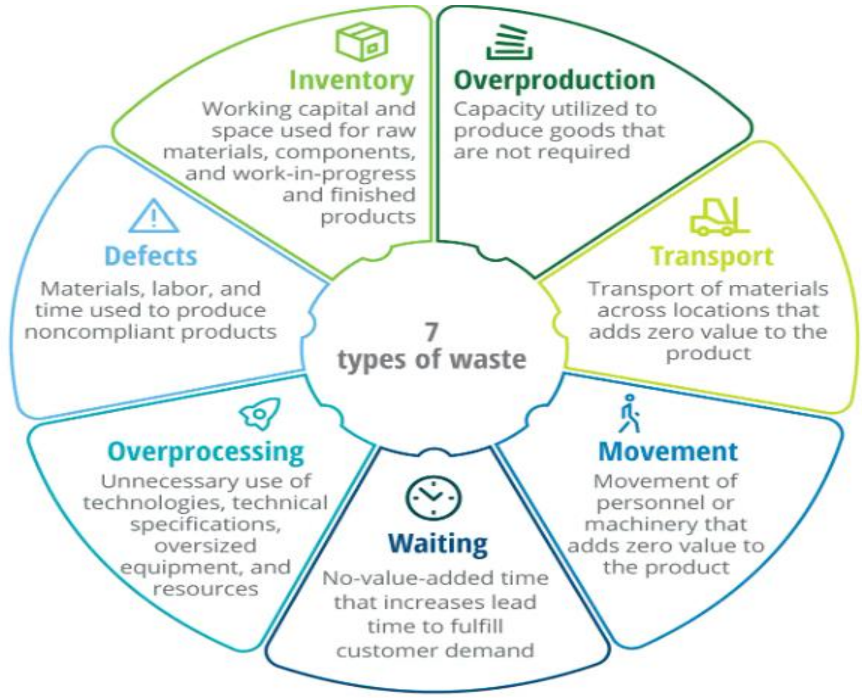


Figure- 2: Seven Types of Wastes.

Seven Types of Wastes

1. Over Production- It is the outcome of not having JIT mechanism where goods from the suppliers are in warded in heap or bulk without planning or getting aligned with plant planning. Producing those goods of which demand is not there is known as over production. High Inventory- It is again the outcome of not having JIT mechanism where goods from suppliers are in warded in bulk or without planning getting aligned with plant planning. Having materials or goods which has no demand and blocking the space and capital is known as inventory
2. Defects- Cost of poor quality is the cost which is incurred due to bad quality of incoming product, damage while assembly or defective material grade. All these happens due to process lapse and not following the Work Instruction & Control Plan. Any product or goods not meeting with the specifications are termed as defects.
3. Over processing- Unnecessary use of sophisticated tools, techniques by which cost of operation increases and is not required by the customers. Any process by which product or goods which are meeting the product standard by par is known as over processing
4. Waiting- Bottlenecks, poor production and operation planning and breakdowns lead to waiting loss of the operators/ workers. Any idle time where no operation is there it is known as waiting time loss.
5. Movement- This waste typically means the movement of working men for doing a specific

task. Higher the movement lower will be the productivity and vice versa. Movement of jumbo and Maini, store keeping is also movement loss if it is scattered

6. Transportation- Scattered good position or untimely goods requirement will increase the transportation waste. Poor planning of materials, Line stoppages, unpredicted urgency of products leads to the transportation loss increasing the carbon footprints.

Table- 1: Effect of Digital lean and Industry 4.0 for Seven Types of Wastes.

Sr. No	Waste type	Present practice in Industries	Digital Lean and Industry 4.0
1	Over Production	Manual planning daily in plant level and monthly planning in tier-1 level	Real time product planning of plant visible to all the tiers for planning adherence and constraint mapping
2	High Inventory	Monthly target given to supplier based on monthly planning	Real time monitoring with Kanban 4.0 which auto calculates the requirement of materials based on their frequency, size, distance, quantity
3	Defects	Sampling inspection is done to validate the lot	Real time monitoring with cluster of the buyoff gates at plant and all the tiers for faster recovery of the product quality
4	Over processing	Class declaration based on customer feedback. A being the most noticeable parts and D & E being the most un noticeable parts	Real time auto DCR getting generated with the feedback from customer, sales and after sales and VAVE team
5	Waiting	TPM for breakdown, MRP for material planning	Real time monitoring and alarming of maintenance activity with desired checklist based on pre-fixed dates and frequencies of parts. Auto DWM development of TPM and MRP
6	Movement	Kitting trolley provided for conveyor parts	Real time auto calculation for throughput and finding out bottlenecks in operation based on TAKT time and material positioning system with the help of Industry 4.0 to optimize the SLT
7	Transportation	One day in advance for full utilization of transportation	Real time tracking system for each and every consignment, raw material procurement, vehicle utilization, SLT for vehicle to reach the plant, Milk route auto planning based on components direction, distance, quantity and timeline

2. Literature Review

A global survey with more than 1000 professionals concluded that emerging digitization and innovations are the driving changes for the industries in planning production and supply chain' (Deloitte, 2018, p. 3). The technology and advancement in supply chain has never been in demand than it is today, as the planning and SCM recovers sharply from the global pandemic with increase in implementation of digital technologies for improving agility, performance and resilience. (Kilpatrick, 2020; Papadopoulos et al., 2020).

The rapid rate of technological advancement is creating the need for adaptation, and the most innovative industries have been the ones that Industries re able to sustain and recognize early on how new digital tools directly affect their business models and what value they can extract from the information generated by their activity (Castelo, Isabel & Cruz, Frederico & Oliveira,

Tiago, 2019). Production processes, business models and corporate governance are badly affected by digital transformation. There is now a strong bond of improvements in IT infrastructure and in analytical capabilities during the past few years since fourth revolution which geared up for innovations for all levels of business models and economic sectors (Castelo, Isabel & Cruz, Frederico & Oliveira, Tiago, 2019).

In order to perform, almost all industries and academia have been taking continuous attempts in developing self-assessment and feedback survey models that can assess the Industry 4.0 readiness of organizations. Evolution of these Industry 4.0 readiness models is also significantly necessary as it will enable industries to measure their readiness in the digital upbringing process which can then head towards organizational transformation (Hanafiah, Hizam & Soomro, Mansoor & Abdullah, 2020) Based on these implications, it will help policy-makers and decision-takers to decide and figure when and how to intervene, and will find out the success in digitalization process and access its implementation strategy. Its high time now if the industries wont lean towards digital transformation then it will be wiped out from entire market (Hanafiah, Hizam & Soomro, Mansoor & Abdullah, 2020).

Today Industries are in that state where they need to know all the information related to that industrial work space sitting in one place and that too updated one sec by sec. Industries agility depends on consumer behaviour which changes more frequently and in demanding nature (Mirela at al, 2019). An industry's ability to implement any new practice or incorporate new technology can be influenced by the perceived catalysts and impediments. The drivers can help while barriers can slow down a new initiative (Ali & Aboelmaged, 2021).

3. Research Gap

The maturity model and industry readiness assessment for various industry is only done with respect to Industry 4.0 implementation but missing its application in Production Planning and Control. Production planning and control is the department which dominates the manufacturing unit in terms of prioritizing the right product in right time but the concept of Industry 4.0 in Production Planning and Control is missing in the past literature. The drivers and Barriers regarding the implementation of Industry 4.0 in Production Planning and Control in the past literatures are missing and untouched.

3.1 Significance of Research

This study will help the organization to find a specific pathway to shorten the execution process between the generations of customer's expectations and fulfilment of the same. This study will provide any industry the new generation technology readiness and deriving the processes hurdles and enablers to work upon them for achieving the set outcomes.

3.2 Research Problem

Production losses in manufacturing industries are increasing steadily over the past ten years, in contrast to other sectors. According to Rasanen (2020), customers are using more digital channels than ten years ago. The consumers has expectations about a service, where she compares these expectations with her perception of the experience. Sudden change or changing expectations results in change in production requirements and production planning. There have been some effective attempts to speed up the processes of fetching the customer

requirements and fulfilling their needs on time, but these interventions have yet to have any significant effect or turnout.

3.3 Research Objectives

The objectives of this research are-

1. To get all the catalysts and impediments required for implementation of Industry 4.0 in Production planning and Control.
2. To find out the most relevant and important Catalysts and impediments required for implementation of Industry 4.0 in Production planning and Control.
3. To prioritize among catalyst for the best among which will support for implementation of Industry 4.0 in Production planning and Control
4. To prioritize among impediments for the worst among which can be avoided for implementation of Industry 4.0 in Production Planning and Control

3.4 Research Methodology

A Mixed method approach is chosen to complete the objectives derived for the research.

3.4.1 Sample Design

All manufacturing industries having Tier 1 or Tier 2 vendors could be stated as the universe. All manufacturing industries top executives in Production planning and control will be considered as Target Population Top Assembly manufacturing industries in Pune region could be termed as sampling Unit. Production Planning and Control department of these industries could be termed as Sampling Frame. Any one expert member of this department of 10-15 industries could be the approximate size of sample. Probability sampling is considered in this research with Cluster sampling method where the universe is very large across the globe. All manufacturing industries having Tier 1 or Tier 2 are considered as homogeneous population and automobile assembly units and related industries in Pune are considered as heterogeneous population.

3.4.2 Proposed Methodology

Table 01: Research Objectives.

S. No.	Research Objectives	Tool Used/ Methodology adopted
A.	To get all the catalysts and impediments required for implementation of Industry 4.0 in Production planning and Control.	Systematic Literature review
B.	To find out the most relevant and important Catalysts and impediments required for implementation of Industry 4.0 in Production planning and Control.	Fuzzy Delphi study
C.	To prioritize among catalyst for the best among which will support for implementation of Industry 4.0 in Production planning and Control	MCDM (BWM)
D.	To prioritize among impediments for the worst among which can be avoided for implementation of Industry 4.0 in Production Planning and Control	MCDM (BWM)

Table 01 is the cluster of all objectives required from this research paper

3.4.3 Research Tools

3.4.3.1 Fuzzy Delphi Method

Fuzzy Delphi method is derived from fuzzy set theory with traditional Delphi technique which is proposed by Ishikawa (1993). Noorderhaben (1995) explained that by applying FDM to a group decision, the solution to the fuzziness of common understanding can be performed, based on the expert's opinions. The FDM forms a different set of weights for a variety of criteria by its application. Delphi is a method of having an expert opinion survey with three features: Anonymous response, controlled feedback and Iteration and finally the statistical group response. Delphi method although usually provides easy understanding for the group opinions through the two times provision of the similar questionnaire. Since FDM merges the fuzzy theory with the FDM, it provides the researchers with add on advantage of Delphi method with reduction of the questionnaire time and cost (Hsu 2010; Yu-Feng 2008). The Delphi method is a process of group decision used to arrive at a group opinion by surveying a panel of experts in multiple rounds. Experts reply to several rounds of questionnaires, and the responses are collected and shared with the same group after each round. The experts are free to adjust their answers based the "group response" provided to them. The ultimate result is the consensus of what the group thinks. Fuzzy Delphi method employs the Triangular Fuzzy set with fuzzy statistics and technique of the conjugate gradient search to fit membership functions.

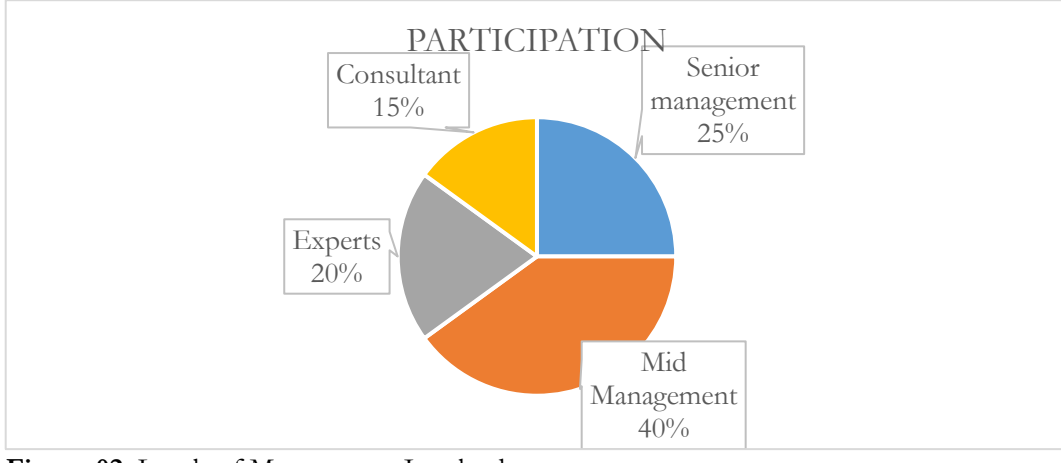


Figure 02: Levels of Management Involved.

The questionnaire was such designed to take inputs from different management levels as mentioned in the Figure 02. The round one of this study constituted 40% of the total experts from mid management level, 25% from senior management level, 20% from Industry experts and 15% from consultants

3.4.3.2 Fuzzy Delphi Calculation

Table 02: Fuzzy Set for Delphi Study.

Variable	Rating scale	Fuzzy Scale
Strongly disagree	1	(0.0, 0.1, 0.2)
Disagree	2	(0.1, 0.2, 0.4)
Not Sure	3	(0.2, 0.4, 0.6)
Agree	4	(0.4, 0.6, 0.8)
Strongly Agree	5	(0.6, 0.8, 1.0)

The above Fuzzy set in Table 02 is derived from the Fuzzy Triangular Number Matrix in which rating scale from 1 to 5 describes from Strongly disagree to Strongly Agree with three vertices

as Strongly disagree with 0.0, 0.1 & 0.2 Disagree with 0.1, 0.2 & 0.4 people with neutral reaction or not sure about the decision will have 0.2, 0.4 & 0.6, Agree stands for 0.4, 0.6 & 0.8 and Strongly Agree means 0.6, 0.8 & 1.0. These Fuzzy sets will replace the rating scale for further Fuzzy calculation.

Data analysis is done with the help of Fuzzy Delphi and Fuzzy triangular Matrix. To view the degree of agreement among experts, a threshold value (d) for two fuzzy numbers m = (m1, m2, m3) and n = (m1, m2, m3) are calculated using the formula:

$$d = \tilde{m},\tilde{n}\sqrt{\frac{1}{3}[(m1-n1)^2+(m2-n2)^2+(m3-n3)^2} \quad (1)$$

Step 1- Building of Likert scale table with the responses collected by 12 different Experts in 1-5 scale for individual 22 catalysts found by in depth literature review

Table 03: Likert scale for Catalysts.

	LIKERT SCALE																
EXPERT	1	2	3	4	5	6	7	8	9	…	….	17	18	19	20	21	22
1	5	2	5	3	1	4	3	3	4	--	--	2	2	2	4	5	4
2	2	5	2	5	5	5	5	5	5	--	--	5	3	4	5	4	4
3	3	1	1	1	2	2	2	3	3	--	--	2	3	3	3	3	2
4	1	2	1	1	2	3	2	3	2	--	--	5	3	2	3	2	2
5	5	3	2	3	5	2	4	3	2	--	--	5	2	2	2	2	3
6	4	1	5	2	5	5	1	3	5	--	--	5	2	5	2	1	2
7	2	2	3	1	5	2	2	3	4	--	--	2	2	2	4	1	3
8	3	2	1	2	5	3	5	5	5	--	--	3	5	5	2	2	2
9	5	4	2	1	5	2	4	4	5	--	--	3	3	3	4	2	4
10	4	3	3	2	5	5	1	1	5	--	--	2	5	2	2	3	2
11	1	2	2	2	1	2	2	2	5	--	--	4	2	2	4	5	4
12	3	1	4	2	5	3	5	3	5	--	--	2	5	2	2	2	2

Table 04: Likert scale for Impediments.

	LIKERT SCALE															
EXPERT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	2	3	5	1	4	4	5	5	5	2	2	4	4	2	4	2
2	2	3	4	2	3	4	4	5	2	3	1	4	2	2	5	2
3	4	4	4	1	5	4	3	3	2	2	2	4	2	2	4	2
4	3	2	4	3	3	3	4	5	4	3	2	4	1	2	5	3
5	1	1	5	1	5	3	3	5	2	1	2	2	1	2	4	3
6	4	1	5	2	4	4	4	5	3	1	2	4	1	2	5	3
7	2	2	4	1	4	2	5	5	4	1	2	4	1	1	4	2
8	3	4	5	2	5	2	4	4	2	1	1	4	1	1	5	3
9	4	4	4	1	4	3	3	4	3	2	1	3	1	1	4	3
10	3	3	4	2	5	2	4	3	4	1	2	5	3	2	5	2
11	1	5	4	2	4	5	5	3	5	3	3	2	2	4	4	3
12	5	5	4	2	5	3	5	4	5	2	2	5	2	2	4	2

The above Table 03 & 04 represents the Likert scale in which 12 Decision makers Industries re considered for fuzzy Delphi and their input against each catalysts and impediments

Industries re noted down in a tabulated column and given their rating scale as stated in Table-2 rating scale, where Strongly disagree stands as 1, Disagree stands as 2, Not sure stands as 3, Agree stands as 4 and Strongly agree stands as 5

Step 2- Building of Triangular Fuzzy scale matrix based on expert input

Table 05: Triangular Fuzzy Scale Matrix for Catalyst.

EXPERT	FUZZY SCALE												
	1			2			----	21			22		
1	0.6	0.8	1	0	0.8	0.4	-----	0.2	0.4	0.6	0	0	0.2
2	0	0.2	0.4	0.6	0.8	1	-----	0.6	0.8	1	0.6	0.8	1
3	0.2	0.4	0.6	0	0	0.2	-----	0	0	0.2	0	0.2	0.4
4	0	0	0.2	0	0.2	0.4	-----	0	0	0.2	0	0.2	0.4
5	0.6	0.8	1	0.2	0.4	0.6	-----	0.2	0.4	0.6	0.6	0.8	1
6	0.4	0.6	0.8	0	0	0.2	-----	0	0.2	0.4	0.6	0.8	1
7	0	0.2	0.4	0	0.2	0.4	-----	0	0	0.2	0.6	0.8	1
8	0.2	0.4	0.6	0	0.2	0.4	-----	0	0.2	0.4	0.6	0.8	1
9	0.6	0.8	1	0.4	0.6	0.8	-----	0	0	0.2	0.6	0.8	1
10	0.4	0.6	0.8	0.2	0.4	0.6	-----	0	0.2	0.4	0.6	0.8	1
11	0	0	0.2	0	0.2	0.4	-----	0	0.2	0.4	0	0	0.2
12	0.2	0.4	0.6	0	0	0.2	-----	0	0.2	0.4	0.6	0.8	1
AVERAGE	0.300	0.478	0.678	0.144	0.344	0.511	-----	0.122	0.278	0.478	0.378	0.544	0.744
	m1	m2	m3	m1	m2	m3	-----	m1	m2	m3	m1	m2	m3

Table 06: Triangular Fuzzy Scale Matrix for Impediments.

	LIKERT SCALE												
EXPERT		1			2				15			16	
1	0	0.2	0.8	0.2	0.4	0.6	-- --	0.4	0.6	0.8	0	0.2	0.8
2	0	0.2	0.8	0.2	0.4	0.6	-- --	0.6	0.8	1	0	0.2	0.8
3	0.4	0.6	0.8	0.4	0.6	0.8	-- --	0.4	0.6	0.8	0	0.2	0.8
4	0.2	0.4	0.6	0	0.2	0.8	-- --	0.6	0.8	1	0.2	0.4	0.6
5	0	0.1	0.0.8	0	0.1	0.0.8	-- --	0.4	0.6	0.8	0.2	0.4	0.6
6	0.4	0.6	0.8	0	0.1	0.0.8	-- --	0.6	0.8	1	0.2	0.4	0.6
7	0	0.2	0.8	0	0.2	0.8	-- --	0.4	0.6	0.8	0	0.2	0.8
8	0.2	0.4	0.6	0.4	0.6	0.8	-- --	0.6	0.8	1	0.2	0.4	0.6
9	0.4	0.6	0.8	0.4	0.6	0.8	-- --	0.4	0.6	0.8	0.2	0.4	0.6
10	0.2	0.4	0.6	0.2	0.4	0.6	-- --	0.6	0.8	1	0	0.2	0.8
11	0	0.1	0.0.8	0.6	0.8	1	-- --	0.4	0.6	0.8	0.2	0.4	0.6
12	0.6	0.8	1	0.6	0.8	1	-- --	0.4	0.6	0.8	0	0.2	0.8
Avg	0.2	0.38	0.76	0.25	0.43	0.78	-- --	0.48	0.68	0.88	0.1	0.3	0.7
	m1	m2	m3	m1	m2	m3		m1	m2	m3	m1	m2	m3

The above Table 04 & 05 is the driven out Triangular Fuzzy scale in which the outputs received by the various decision makers against each 22 catalysts and 16 impediments are formulated based on the Fuzzy sets tabulated in the Table 02. The table stands as Strongly disagree with 0.0, 0.1 & 0.2 Disagree with 0.1, 0.2 & 0.4 people with neutral reaction or not sure about the decision will have 0.2, 0.4 & 0.6, Agree stands for 0.4, 0.6 & 0.8 and Strongly Agree means 0.6,

0.8 & 1.0. These Fuzzy sets will replace the rating scale for further Fuzzy calculation. In this average of each column is calculated and denoted as m1, m2, m3 respectively for each Readiness factor decisions given by 12 decision makers.

Step 3- Finding out the threshold "d" value

Table 07: Threshold Matrix.

EXPERT	ITEM								
	1	2	3	-----	-----	19	20	21	22
1	0.5	0.5	0.4	---	---	0.3	0.0	0.1	0.0
2	0.4	0.3	0.5	---	---	0.6	0.6	0.5	0.3
3	0.6	0.5	0.4	---	---	0.3	0.3	0.1	0.3
4	0.7	0.2	0.5	---	---	0.0	0.3	0.1	0.6
5	0.5	0.1	0.5	---	---	0.3	0.3	0.1	0.6
6	0.2	0.5	0.5	---	---	0.6	0.6	0.1	0.3
7	0.4	0.2	0.4	---	---	0.3	0.3	0.1	0.0
8	0.3	0.2	0.1	---	---	0.0	0.6	0.5	0.3
9	0.5	0.4	0.1	---	---	0.3	0.3	0.2	0.3
10	0.2	0.1	0.4	---	---	0.6	0.6	0.7	0.3
11	0.7	0.2	0.2	---	---	0.3	0.3	0.4	0.3
12	0.7	0.5	0.4	---	---	0.0	0.6	0.1	0.3
Value of d each item	0.475	0.308	0.367			0.300	0.400	0.250	0.475
Value of d construct				0.350					

The above calculation in Table 05 has given the individual threshold value "d" for all 22 catalysts and 16 impediments as 0.350 which was identified by in depth literature survey. With the criteria of d≤0.2 and expert group consensus above 75% Industries came up with 9 nos of catalysts and 9 nos of impediments which was declared as most effective catalysts and most avoidable impediments for implementation of Industry 4.0 in Production Planning and Control. The value of construct is formulated by defuzzification of the fuzzy matrix by the formula of threshold value and then taking out the average of each column to identify the threshold of that particular readiness factor and rate them with group consensus.

Fuzzy Delphi Result

For Catalyst

- Technology upgradation
- Digitization
- Connectivity
- Competitive edge
- Business KPI
- Leadership
- Application
- ROBOTS
- IOT based system

For Impediments

- Low level leadership
- Central Data ownership
- Inhouse talent
- Integration with existing networking
- High-fi level knowledge building
- IT prerequisite
- Budget allocation
- Forecasting immediate return
- High labour volume

After calculating with Fuzzy Delphi study Industries got to know that 12 different experts have suggested that 9 different catalysts and 9 different impediments are to be considered for implementation of Industry 4.0 in Production planning and control. With the completion of Fuzzy Delphi Study, 22 catalysts and 16 impediments got reduced to 9 effective catalysts and 9 impediments.

3.4.3.3 BWM Method

Rezaei (2015) introduced BWM (Best Worst Method), and Guo and Zhao (2017) developed BWM. Initially, determine the decision goal and identify the various criteria to evaluate any decision-making problem. BWM is not a matrix based MCDM method but it is a vector based method with feIndustries r comparisons.

The BWM is a method that has been derived and developed to solve MCDM problems (Rezaei, 2015, 2016) and that is based on pairwise comparison based on vector calculation. BWM has two key advantages over other MCDM approaches of decision making.

i) Comparison data needed is less compared to full pairwise matrix.
ii) The results of BWM are more consistent than other MCDM methods.

This method is getting utilized in several real-world issues. For example, Rezaei et al. (2016a) used BWM for determining best freight bundling configuration from outstations to airports. In another study by Rezaei et al. (2016b), best suppliers were selected considering environmental and economic criteria.

3.4.3.4 Determination of Decision Criteria

In this initial step, the decision-makers had identified a set of criteria which describes the subject. This section highlights the developmental and refinement processes of the paper. These criteria of Catalysts and Impediments Industries re identified through in-depth literature review and 12 decision- makers of Top Auto Industries input which belongs to the senior most position in their respective companies. From the literature review, 4 criteria of catalysts and 4 criteria of Impediments Industries re selected by the decision. The experts Industries re given a questionnaire with different criteria to rate them among 1 to 5 in which 1 stands for poor relevant and 5 stands for most relevant. Out of 14 different criteria selected through in-depth literature review, eight catalyst and Impediments criteria Industries re selected

Table 8: Criteria Selected for the Assessment of Catalyst.

Criteria	Criteria ABB	Short description
Technological Readiness	C1	Technology needs to be analyzed for its readiness for implementing Industry 4.0 in any Industry
Technology security	C2	Online platforms where data needs to be secured for any business related data transfer
Organizational readiness	C3	Organization update for incorporating new technology and internet based readiness for any industry
Financial commitment	C4	Having required budget and commitment from senior management for implementation of Industry 4.0 projects

Table 9: Criteria Selected for the Assessment of Impediments

Criteria	Criteria ABB	Short description
Budgetary approval process	I1	Budget approval process should not be lengthy and time taking
Implementation timeline	I2	Implementation timeline should be mapped and forecasted before project initiation
Leadership	I3	Involvement of senior leadership is required
Organizational readiness	I4	Organization update for incorporating new technology and internet based readiness for any industry

3.4.3.5 Identifying the Best and the Worst Catalyst and Impediments

In the second step, these 9 criteria of Catalyst assessment and Impediment assessment Industries re circulated with the list of catalyst and Impediment identified through Fuzzy Delphi study to 178 respondents from the top auto makers across the nation. The ratings given on each catalyst and impediments are based on the criteria identified by the 12 decision makers which specified the most and the least important catalyst and impediments. With the 12 decision makers and criteria identified above, the Best catalyst selected was "Connectivity" and worst catalyst selected was "Technology upgradation". Similarly the Best Impediment selected was "Low level leadership" and worst impediment selected was "Budget". The resulting best and worst are listed in Table 3.

Names of Criteria	Technology upgradation	Digitization	Connectivity	Competitive edge	Business KPI	Leadership	Application	ROBOTS	IOT based system

Select the Best	Connectivity

Select the Worst	Technology

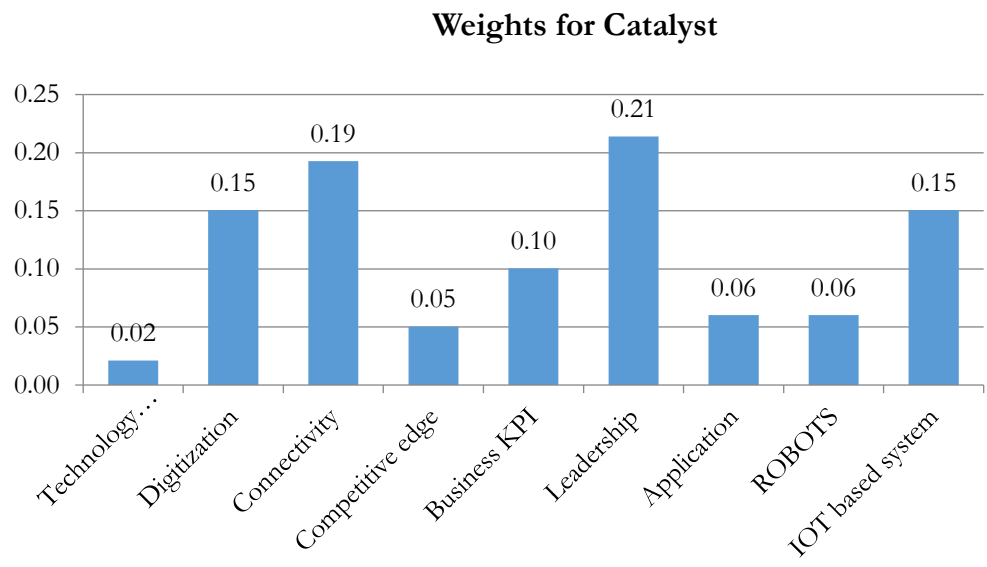
Best to Others	Technology upgradation	Digitization	Connectivity	Competitive edge	Business KPI	Leadership	Application	ROBOTS	IOT based system
Connectivity	4	2	1	6	3	1	5	5	2

Others to the Worst	Technology
Technology	1
Digitization	4
Connectivity	7
Competitive edge	3
Business KPI	7
Leadership	5
Application	8
ROBOTS	3
IOT based system	2

Weights	Technology upgradation	Digitization	Connectivity	Competitive edge	Business KPI	Leadership	Application	ROBOTS	IOT based system
	0.02	0.15	0.19	0.05	0.10	0.21	0.06	0.06	0.15

Ksi*	0.10843373

BWM Calculation for Catalys



BWM calculation for Impediments

Names of Criteria	Low level leadership	Central Data ownership	Inhouse talent	Integration with existing networking	High-fi level knowledge building	IT prerequisite	Budget allocation	Forecasting immediate return	High labour volume
Select the Best	Low level								
Select the Worst	Budget								

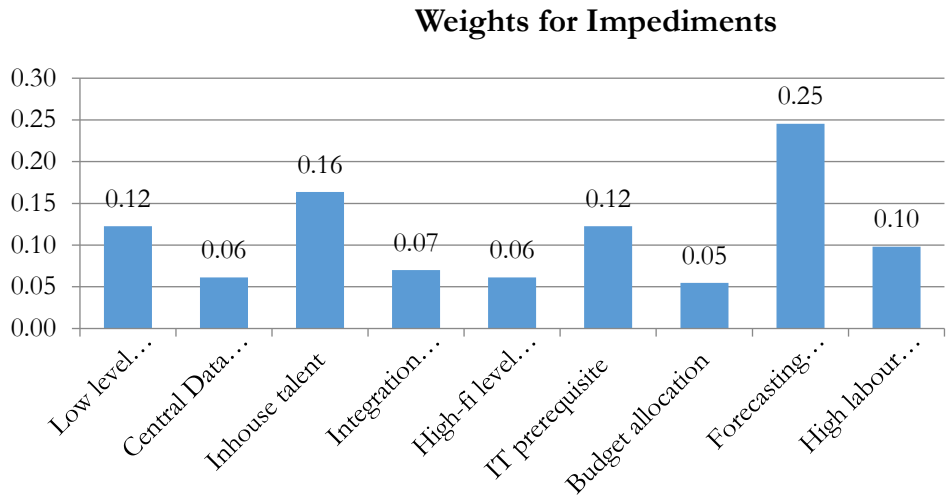
Best to Others	Low level leadership	Central Data ownership	Inhouse talent	Integration with existing networking	High-fi level knowledge building	IT prerequisite	Budget allocation	Forecasting immediate return	High labour volume
Low level leadership	4	8	3	7	8	4	9	2	5

Others to the Worst	Budget
Low level leadership	9
Central Data	5
Inhouse talent	6
Integration with	6
High-fi level	8
IT prerequisite	4
Budget allocation	8
Forecasting immediate	3
High labour volume	5

Weights	Low level leadership	Central Data ownership	Inhouse talent	Integration with existing networking	High-fi level knowledge building	IT prerequisite	Budget allocation	Forecasting immediate return	High labour volume
	0.12	0.06	0.16	0.07	0.06	0.12	0.05	0.25	0.10

Ksi*	0.4908453

After performing various statistical calculation among respondents for the preference of the decision-maker on "the Best criterion over all the other criteria", and the preference of "all the other criteria over the Worst" by selecting a number 1 and 9 from the drop-box, the above bar graph represents the Industries weights of catalyst



After performing various statistical calculation among respondents for the preference of the decision-maker on "the Best criterion over all the other criteria", and the preference of "all the other criteria over the Worst" by picking up a number 1 and 9 from the drop-box, the above bar graph represents the Industries weights of impediments

4. Results and Discussion

Based on the statistical calculation over the answers received from the various respondents, Industries analysed that Leadership is the biggest and effective catalyst any industry should be working upon initially and Industries should avoid arguing upon forecasting immediate return for the investment incurred for installation of Industry 4.0 technologies. With above analysis Industries can rate the catalysts from most important or effective as Rank-1 and least effective as Rank-7. Industries should focus on having a strong and top down approach leadership which will accelerate the implementation of Industry 4.0 in PPC. Industries should focus on connecting the vendors, dealers, shops etc through digital media and Internet which will start the phase 1 (Application) of implementation of Industry 4.0 in PPC. ROBOTS are the low hanging fruits which all industries should focus upon connecting them through IOT. Industries should also focus on the competition outside for usage and application of technology in their firms and what advantage they are enjoying and similarly we can upgrade our technology and enjoy the same or better benefits.

LIST OF CATALYSTS	RANK
Leadership	1
Connectivity	2
Digitization	3
IOT based system	3
Business KPI	4
Application	5
ROBOTS	5
Competitive edge	6
Technology upgradation	7

Similarly for Impediments. Biggest hurdle is ranked 1 and smallest hurdle as Rank-7. This states that Industries should avoid forecasting for immediate returns. Industries should also not rely on inhouse talent for implementation of Industry 4.0 in PPC and Industries should approach for technical expert at least in the initial phase of implementation. Industries should never go with low level leadership for Industry 4.0 project of PPC implementation. Industries should also not wait for IT prerequisites to complete for starting Industry 4.0 PPC projects. Industries should also not hire high labour initially for implementation of Industry 4.0 in PPC. Industries should not go for integration of Industry 4.0 in existing networking as this phase may take a bit of time which may hamper regular activities. The data should not be centrally owned as Industry 4.0 is known for data connectivity and there should be fragmentation of the data ownership for debugging it quickly and effectively. Industries should also not go for developing high level knowledge for their work men to implement Industry 4.0 in PPC. Industry should also not keep on asking for the budget everytime for Industry 4.0 projects which may dilute the crux of the benefit by implementing Industry 4.0 in PPC.

LIST OF IMPEDIMENTS	RANK
Forecasting immediate return	1
Inhouse talent	2
Low level leadership	3
IT prerequisite	3
High labour volume	4
Integration with existing networking	5
Central Data ownership	6
High-fi level knowledge building	6
Budget allocation	7

References

Deloitte, 2018. Overcoming barriers to NextGen supply chain innovation. In: The MHI Annual Industry Report.

Gökalp, Ebru & Sener, Umut & Eren, P.. (2017). Development of an Assessment Model for Industry 4.0: Industry 4.0-MM. 128-142. 10.1007/978-3-319-67383-7_10.

Gupta, H., & Barua, M. K. (2017). Supplier selection among SMEs on the basis of their green innovation ability using BWM and fuzzy TOPSIS. *Journal of Cleaner Production*, *152*, 242-258.

Gupta, P., Anand, S., & Gupta, H. (2017). Developing a roadmap to overcome barriers to energy efficiency in buildings using best worst method. *Sustainable Cities and Society*, *31*, 244-259.

John L. Hopkins, An investigation into emerging industry 4.0 technologies as drivers of supply chain innovation in Australia, Computers in Industry, Volume 125, 2021, 103323, ISSN 0166-3615, https://doi.org/10.1016/j.compind.2020.103323.

Khin, S., & Kee, D. M. H. (2022). Factors influencing Industry 4.0 adoption. *Journal of Manufacturing Technology Management*.

Khin, S., & Mui Hung, D. K. (2022). Identifying the driving and moderating factors of Malaysian SMEs' readiness for Industry 4.0. *International Journal of Computer Integrated Manufacturing*, 1-19.

Pramod Kumar, Jaiprakash Bhamu, Kuldip Singh Sangwan, Analysis of Barriers to Industry 4.0 adoption in Manufacturing Organizations: an ISM Approach, Procedia CIRP, Volume

98, 2021, Pages 85-90, ISSN 2212-8271, https://doi.org/10.1016/j.procir.2021.01.010.

Rejab, Mazidah & Firdaus, Nurulhuda & Chuprat, Suriayati. (2019). Fuzzy Delphi Method for Evaluating HyTEE Model (Hybrid Software Change Management Tool with Test Effort Estimation). International Journal of Advanced Computer Science and Applications. 10. 10.14569/IJACSA.2019.0100465.

Sharad Rajbhandari, Niranjan Devkota, Ghanashyam Khanal, Surendra Mahato, Udaya Raj Paudel, Assessing the industrial readiness for adoption of industry 4.0 in Nepal: A structural equation model analysis, Heliyon, Volume 8, Issue 2, 2022, e08919, ISSN 2405-8440, https://doi.org/10.1016/j.heliyon.2022.e08919.

Sony, Michael & Naik, Subhash. (2019). Key ingredients for evaluating Industry 4.0 readiness for organizations: a literature review. Benchmarking An International Journal. 10.1108/BIJ-09-2018-0284.

Sriram, R.M. & Vinodh, Sekar. (2020). Analysis of readiness factors for Industry 4.0 implementation in SMEs using COPRAS. International Journal of Quality & Reliability Management. 38. 1178-1192. 10.1108/IJQRM-04-2020-0121.

Stentoft, J., Adsbøll Wickstrøm, K., Philipsen, K., & Haug, A. (2020). Drivers and barriers for Industry 4.0 readiness and practice: empirical evidence from small and medium-sized manufacturers. *Production Planning & Control*, 1-18.

Stentoft, J., Jensen, K. W., Philipsen, K., & Haug, A. (2019, January). Drivers and barriers for Industry 4.0 readiness and practice: a SME perspective with empirical evidence. In *Proceedings of the 52nd Hawaii International Conference on System Sciences*.

Türkeş, M. C., Oncioiu, I., Aslam, H. D., Marin-Pantelescu, A., Topor, D. I., & Căpuşneanu, S. (2019). Drivers and barriers in using industry 4.0: a perspective of SMEs in Romania. *Processes*, *7*(3), 153.

Vishal Ashok Wankhede, S. Vinodh, Analysis of Industry 4.0 challenges using best worst method: A case study, Computers & Industrial Engineering, Volume 159, 2021, 107487, ISSN 0360-8352, https://doi.org/10.1016/j.cie.2021.107487.