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อุตสาหกรรม และการผลิต ในยุค THAILAND 4.0

NOW & NEXT

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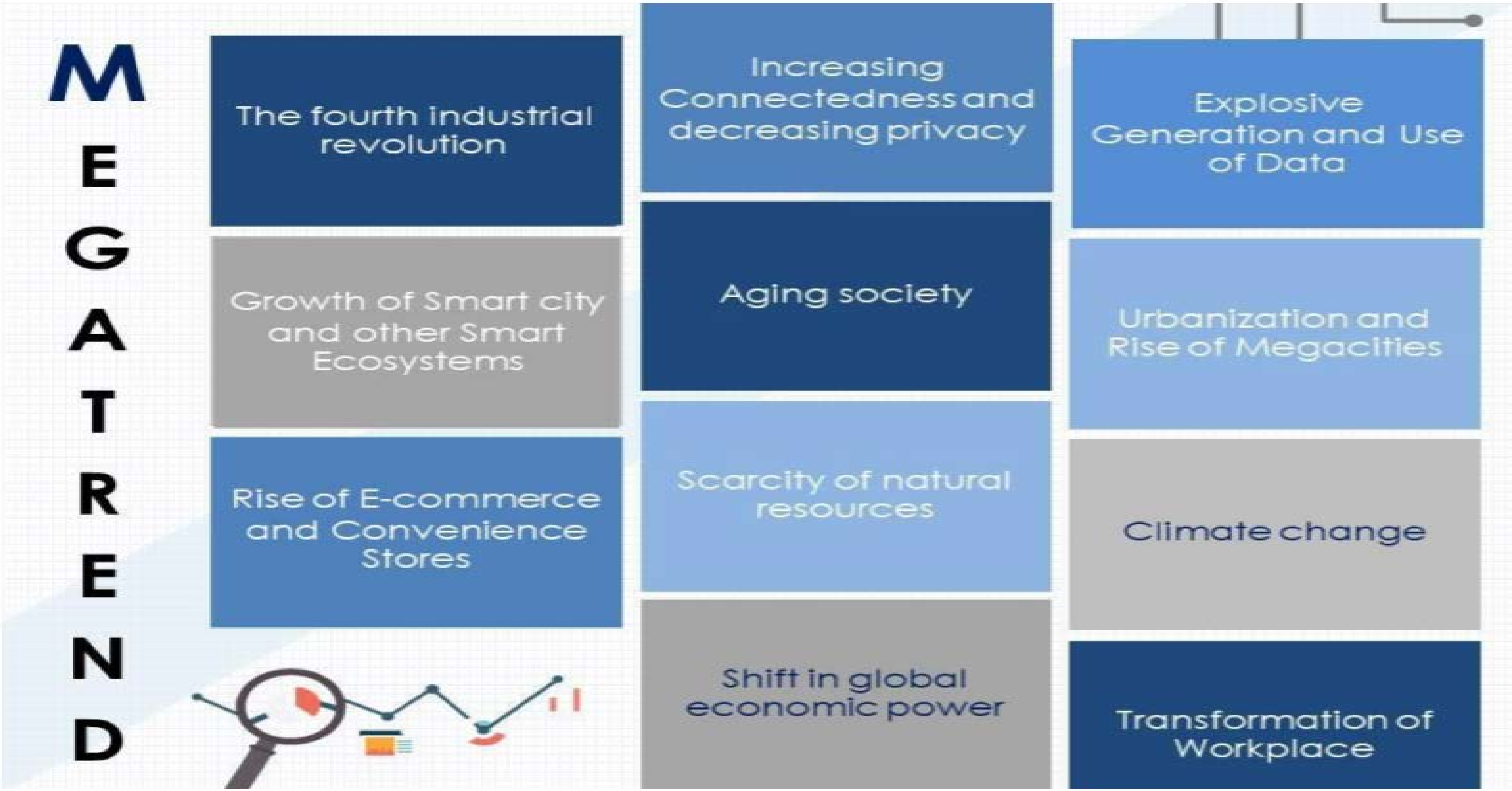
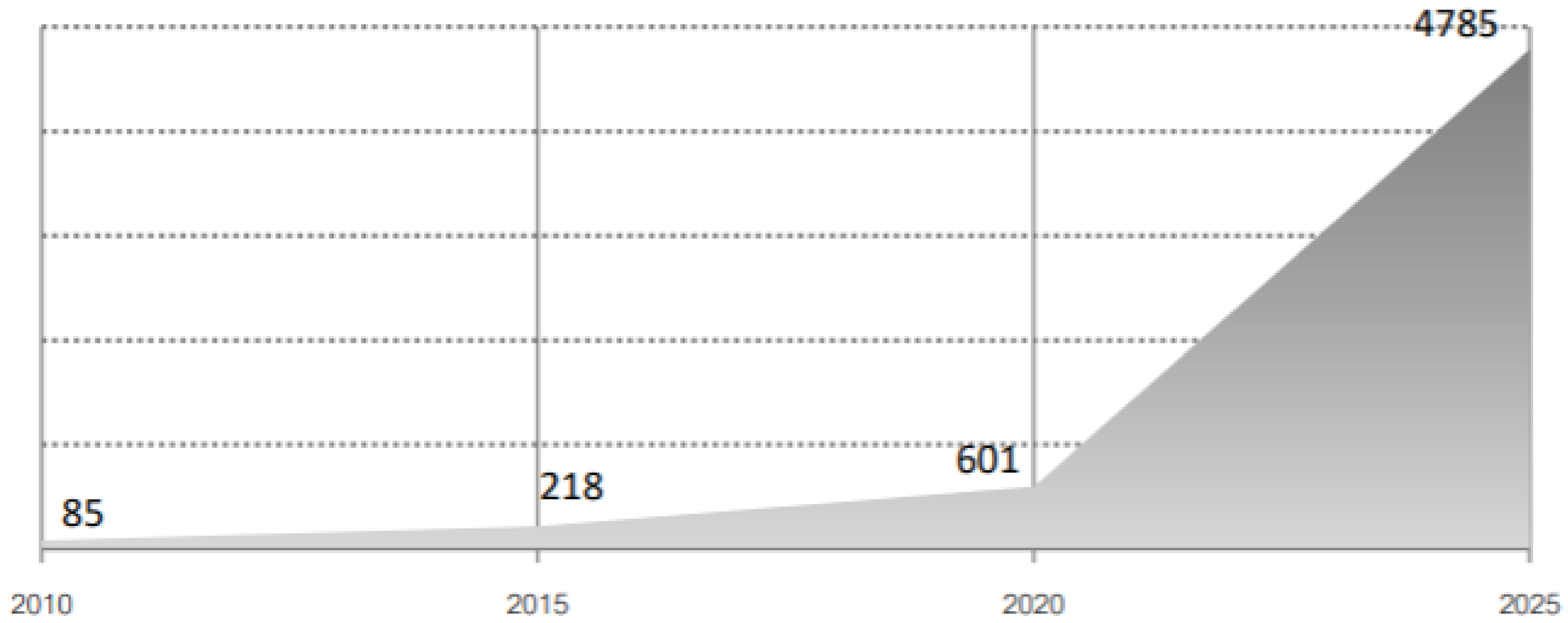
สิ่งที่จะได้รับใน Session นี้

1. เข้าใจวิวัฒนาการด้าน IOT และการพัฒนาอย่างต่อเนื่อง
2. มองเห็นภาพการเติบโตของอุตสาหกรรมไทยอดีต ปัจจุบัน และ อนาคต
3. เห็นแนวทางการพัฒนาของอุตสาหกรรม 4.0 ในอนาคตของโลก
4. แนวทางการปรับตัวของประเทศไทยต่อวิวัฒนาการ


MEGATREND
The fourth industrial revolution
Growth of Smart city and other Smart Ecosystems
Rise of E-commerce and Convenience Stores
Increasing Connectedness and decreasing privacy
Aging society
Scarcity of natural resources
Shift in global economic power
Explosive Generation and Use of Data
Urbanization and Rise of Megacities
Climate change
Transformation of Workplace

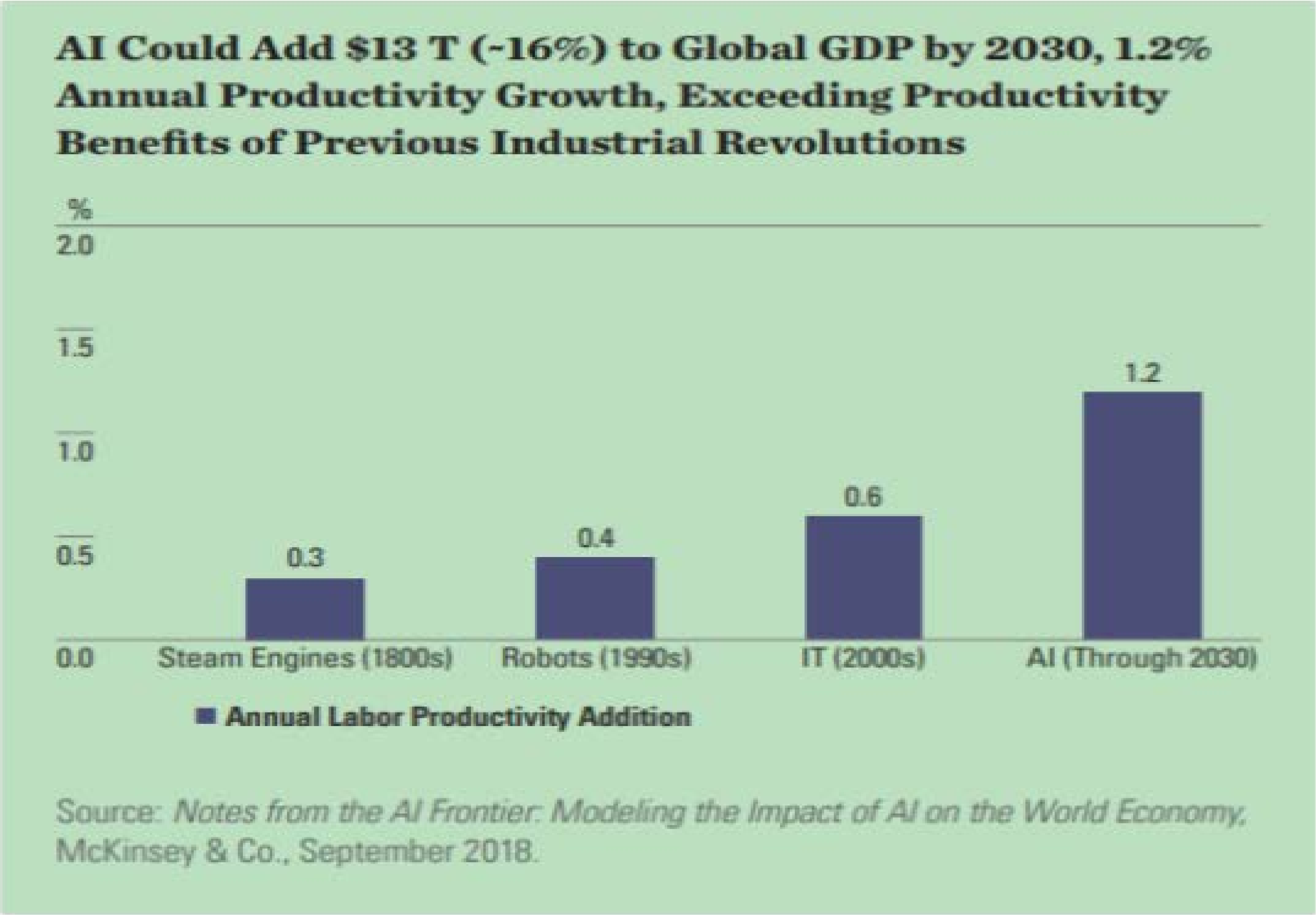
Number of times people interact with connected devices

Estimated daily interactions for the average connected person globally



Source: IDC

AI Could add US$13 trillion to Global GDP by 2030



Most valuable companies in the world 2019

Company		Industry	Market Capitalization
#1	**Amazon Inc.**	Retail business	$802.18 billion
#2	**Microsoft**	Software development	$789.25 billion
#3	**Alphabet Inc.**	Internet with various digital platforms	$737.37 billion
#4	**Apple Inc.**	Electronics, Information Technology	$720.12 billion
#5	**Berkshire Hathaway Inc.**	Insurance, finances, railway transport, utilities, food and non-food products	$482.36 billion
#6	**Facebook**	Internet with social network platform	$413.25 billion
#7	**Tencent**	Internet with social network platform	$400.95 billion
#8	**Alibaba Group**	Internet with E-Commerce platform	$392.25 billion
#9	**Johnson & Johnson**	Pharmaceuticals	$347.99 billion
#10	**JPMorgan Chase**	Banking business	$332.24 billion

Source: FXSSI

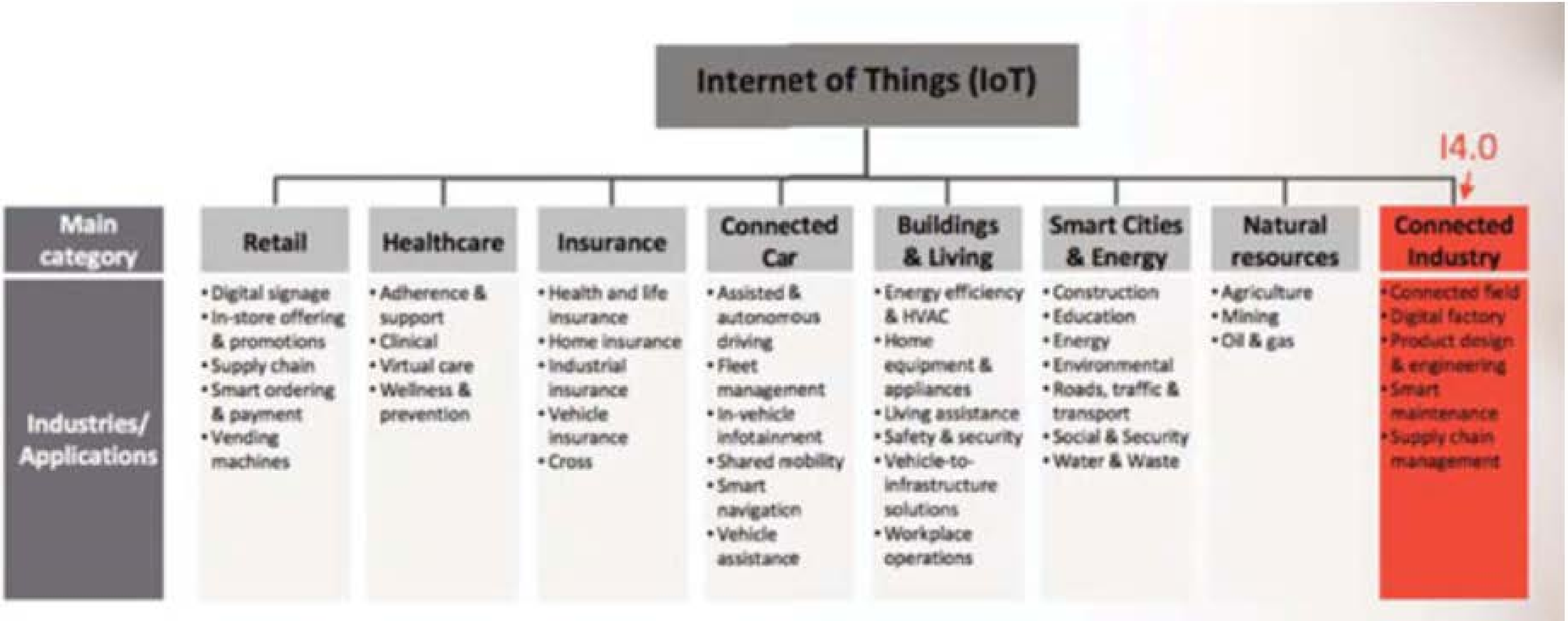
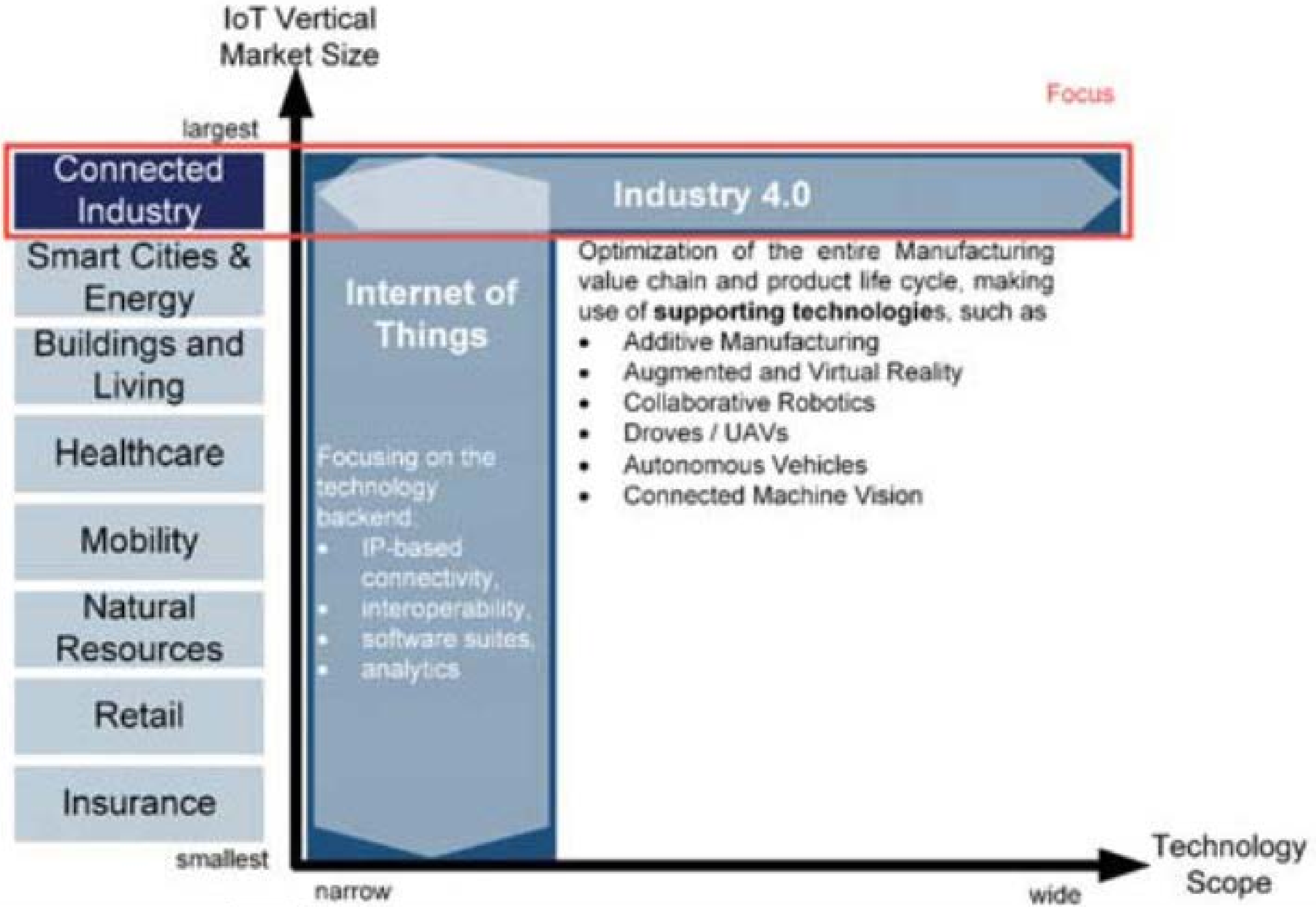
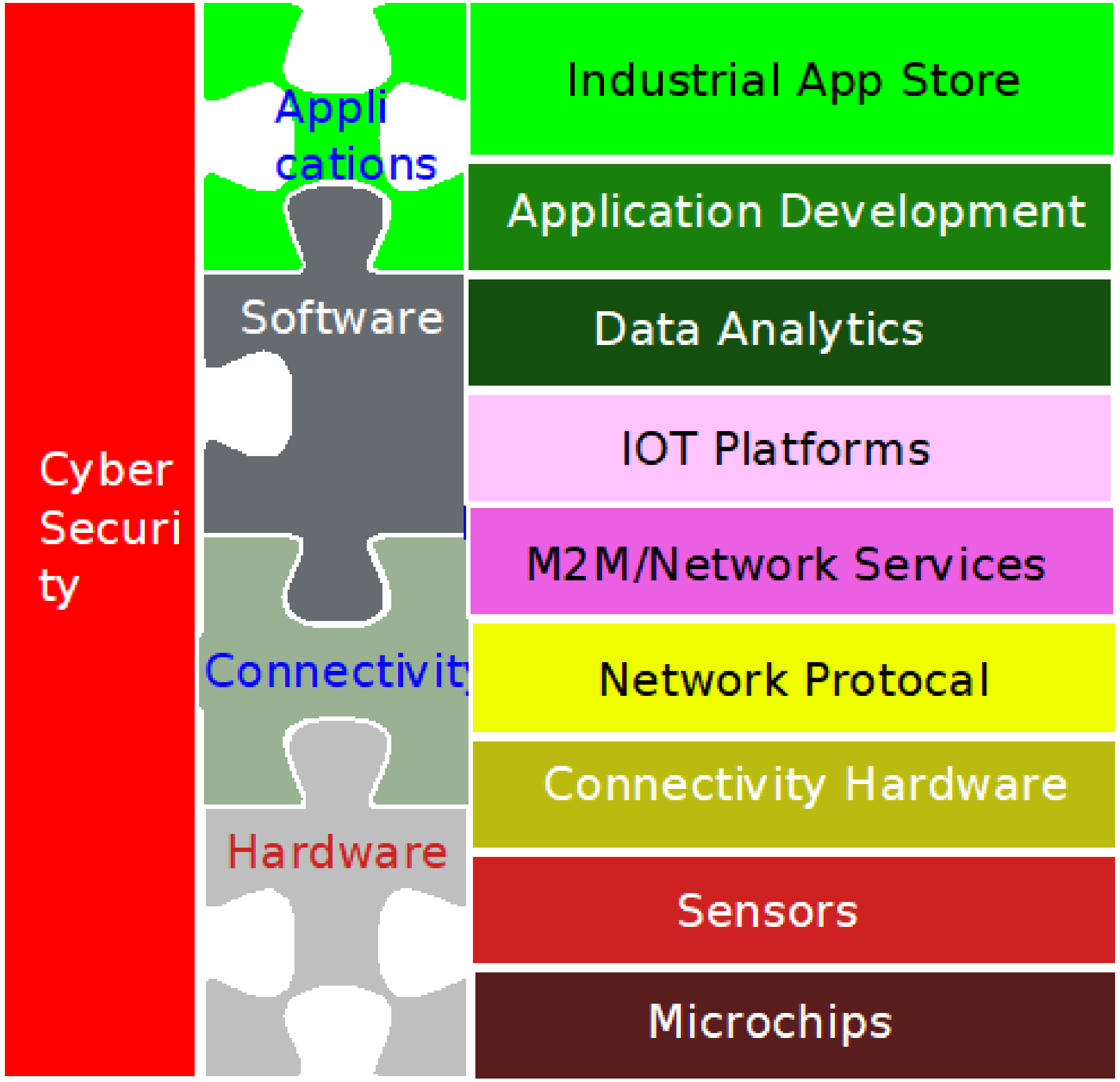


Figure 1: IoT segments, from least to most industrial

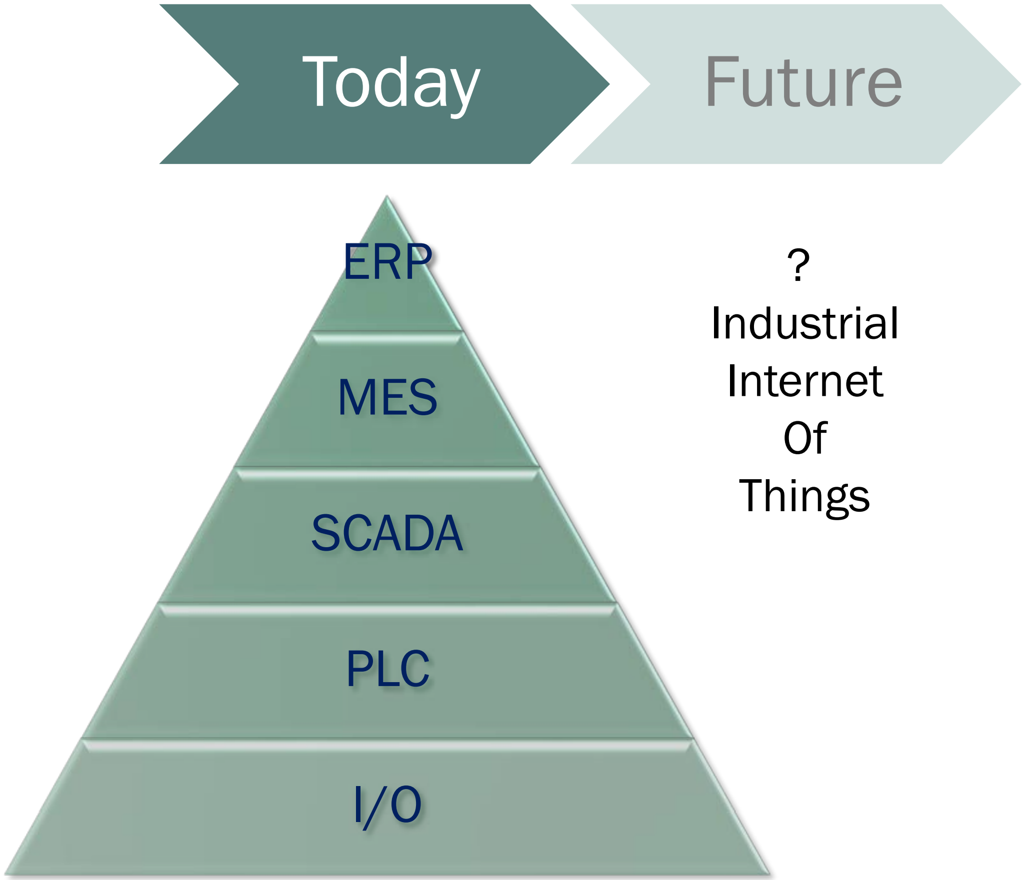


IoT Vertical Market Size
largest
smallest
Focus
Connected Industry
Smart Cities & Energy
Buildings and Living
Healthcare
Mobility
Natural Resources
Retail
Insurance
Industry 4.0
Internet of Things
Focusing on the technology backend
• IP-based connectivity,
• interoperability,
• software suites,
• analytics
Optimization of the entire Manufacturing value chain and product life cycle, making use of supporting technologies, such as
• Additive Manufacturing
• Augmented and Virtual Reality
• Collaborative Robotics
• Droves / UAVs
• Autonomous Vehicles
• Connected Machine Vision
narrow
wide
Technology Scope

6 IIOT Building Blocks



Disrupted Technology



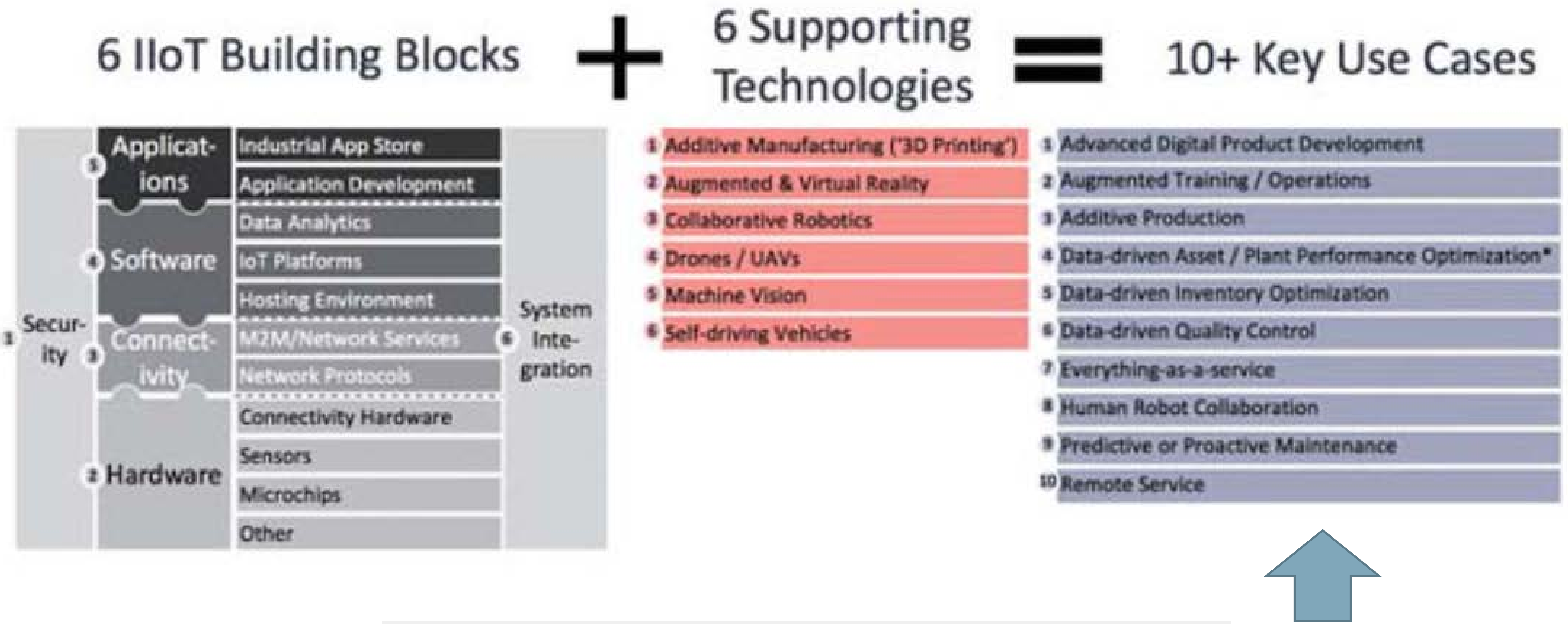
Automation
Pyramid

Supporting Technology

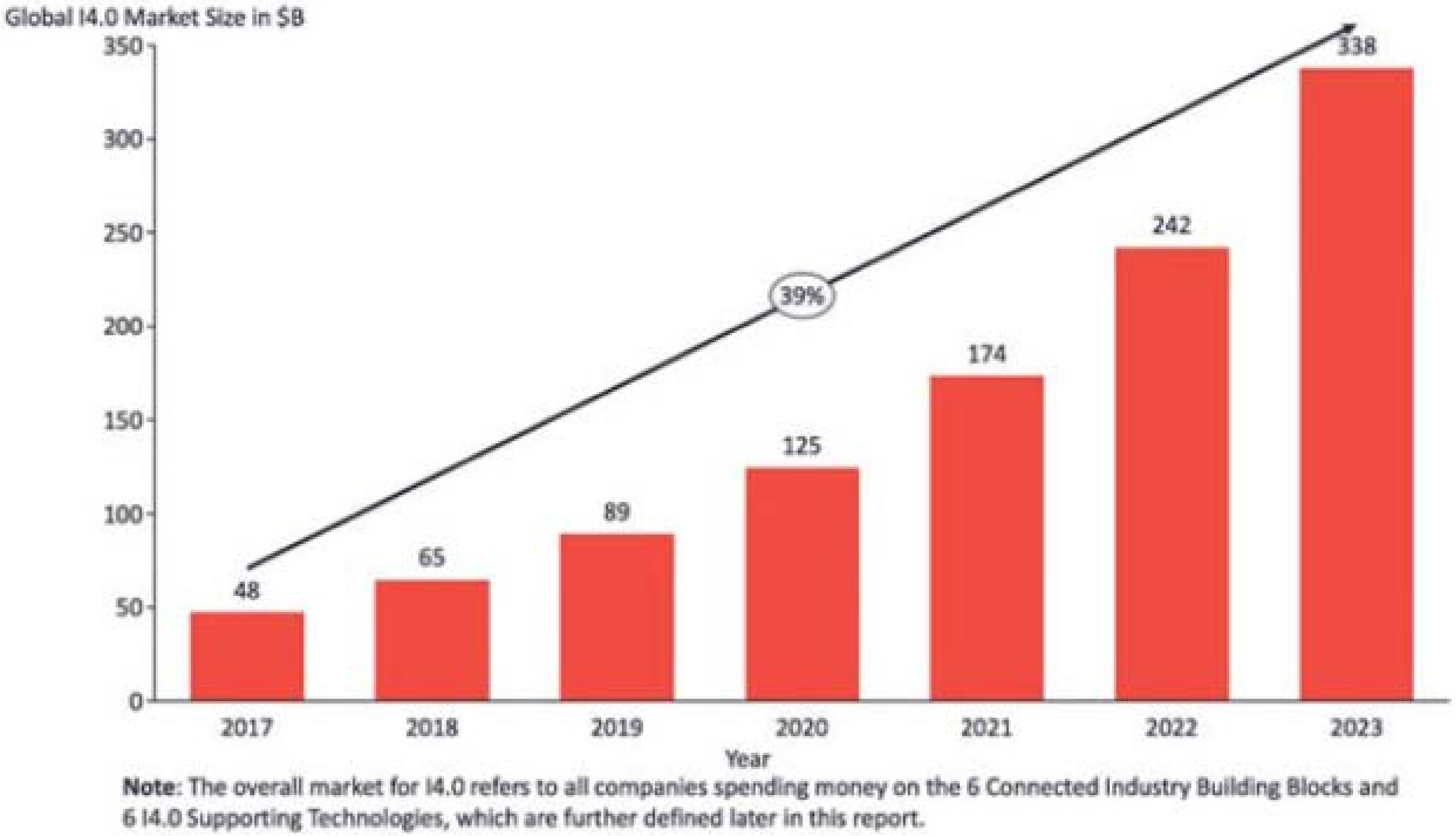
- Additive Manufacturing
- Augmented & Virtual Reality
- Collaborative Robotics
- Drones/UAVs
- Machine Vision
- Self-driving Vehicles

Key Use Cases

- Advanced Digital Products
- Augmented Training
- Additive Production
- Data-driven Asset
- Data-driven Inventory
- Data-driven Quality Control
- Everything-as-a-service
- Human Robot Collaboration
- Predictive Maintenance
- Remote Service



Definition of Industry 4.0 addressable market



Predicted growth of Industry 4.0 market

The growth of the market for I4.0 solutions is largely driven by three types of value derived from the I4.0 use cases:

1. **Efficiency gains across the whole organisation:** Many industrial organisations have estimated productivity gains from investments in I4.0 technologies to be ~25%. **Fanuc** and **Cisco** recently partnered to create an IIoT enabled predictive maintenance platform that is improving customers' overall equipment efficiencies (OEE) by eliminating unplanned downtime. One Fanuc customer saved an estimated US$40m in downtime using this connected platform.

2. **New revenue streams:** OEMs are using IIoT technology to create new x-as-a-service business models. These pay-per-outcome business models better align OEMs with customers' objectives by incentivising OEMs to make sure their machines are operating properly. Machine tool OEM **Heller** uses the **Siemens** MindSphere platform to allow customers to pay for machine usage by the hour. OEM **Kaeser Compressors** takes this model even further, allowing its customers to pay for compressed air by the cubic metre.

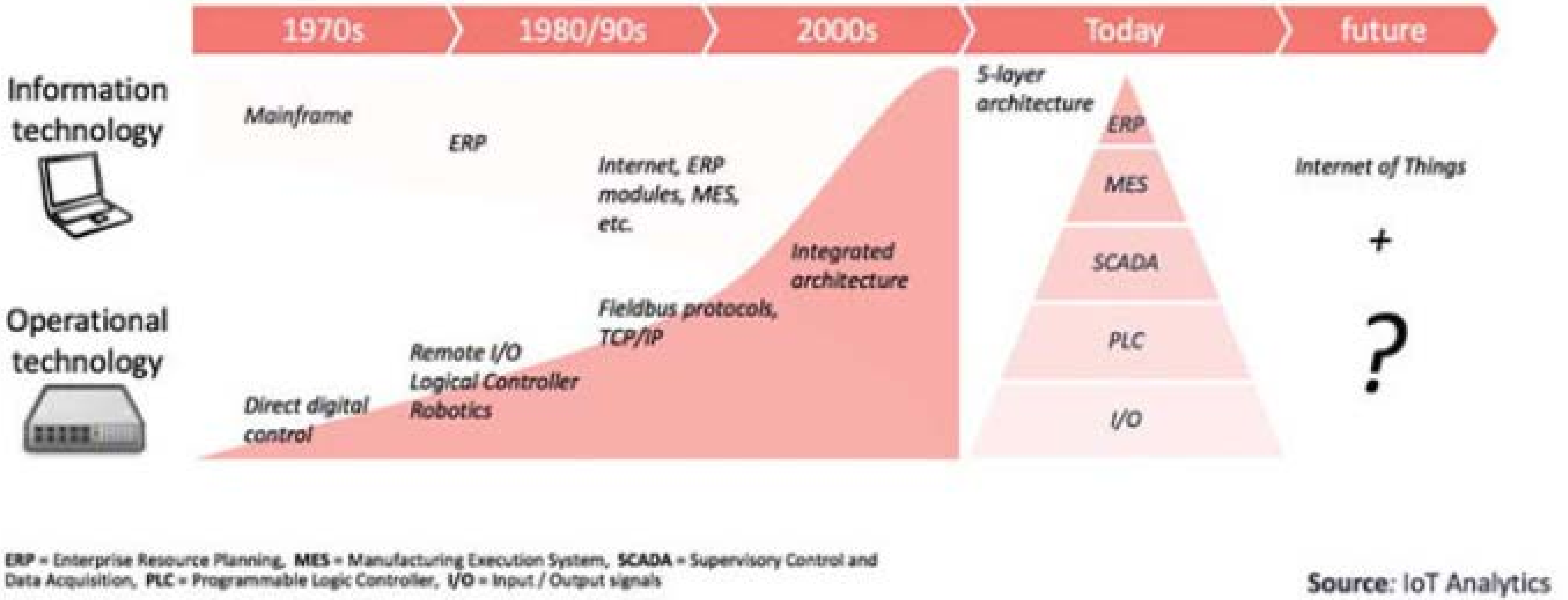
3. More flexible, customer centric operations that reduce time-to-market: I4.0 technologies enable manufacturers to be more flexible in all stages of the product development lifecycle. Engineers at **Volvo Construction Equipment** recently adopted 3D printing technology to help with rapid prototyping of new parts. By using 3D printing instead of traditional tooling methods, Volvo was able to cut both the development time and cost per part by 90%.

Disrupted technologies: the automation pyramid

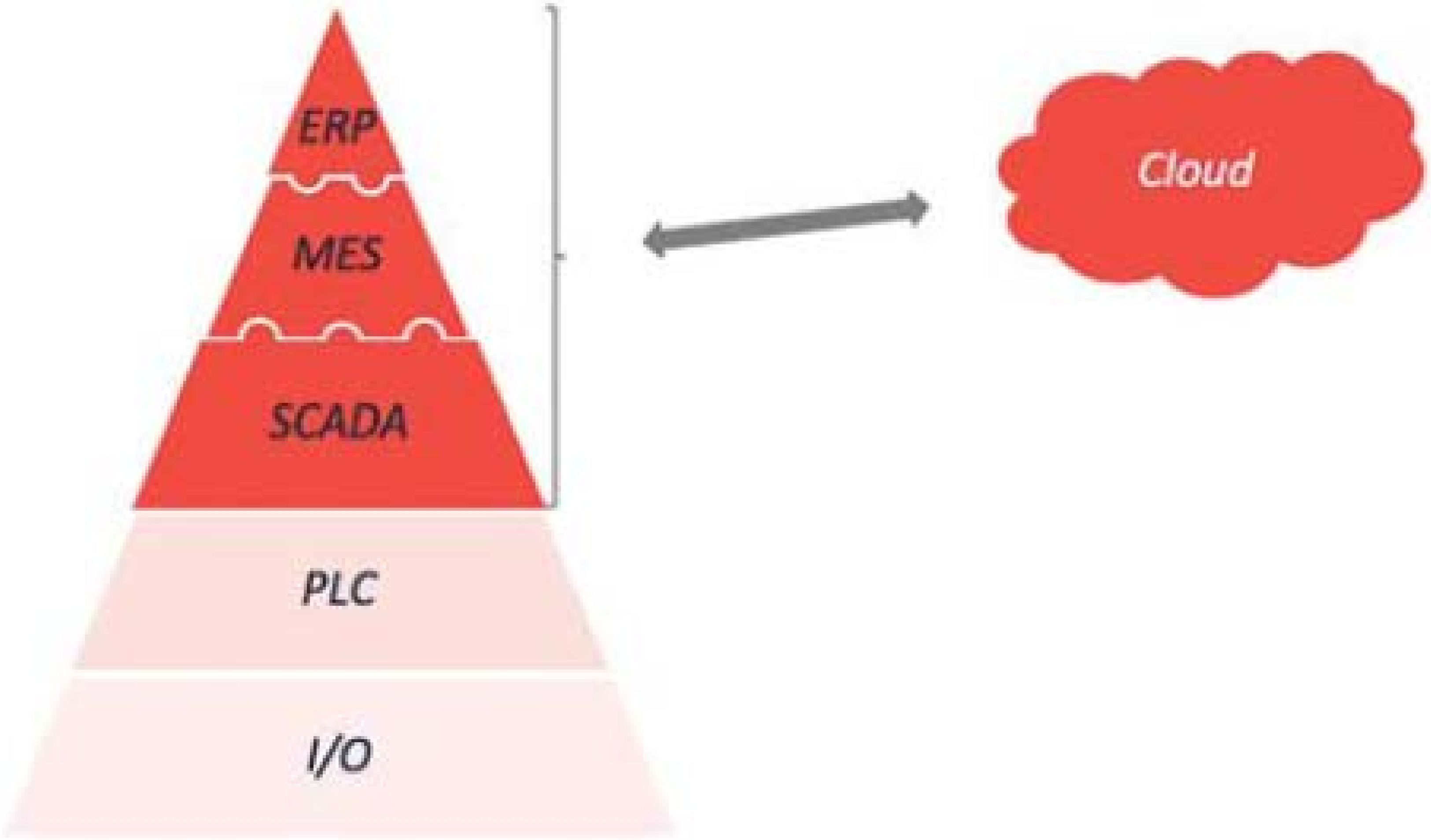
The five-layered technology architecture, which has established itself over the last 50+ years, is one of the core elements likely to be disrupted through Industry 4.0. The pyramid is the result of the decades-long convergence of information technology (IT) and operational technology (OT) and is widely accepted as the standard high-level architecture in manufacturing environments.

The term OT is usually used for computer processing technology in the physical world of manufacturing technology, including programmable logic controller (PLC), distributed control system (DCS) and supervisory control and data acquisition (SCADA). These technologies have been used in isolated vertical applications and have been controlled locally with the help of proprietary protocols. IT on the other hand has been deployed in administration and management, for example coming in the form of enterprise resource planning (ERP), customer relationship management (CRM) or manufacturing execution systems (MES).

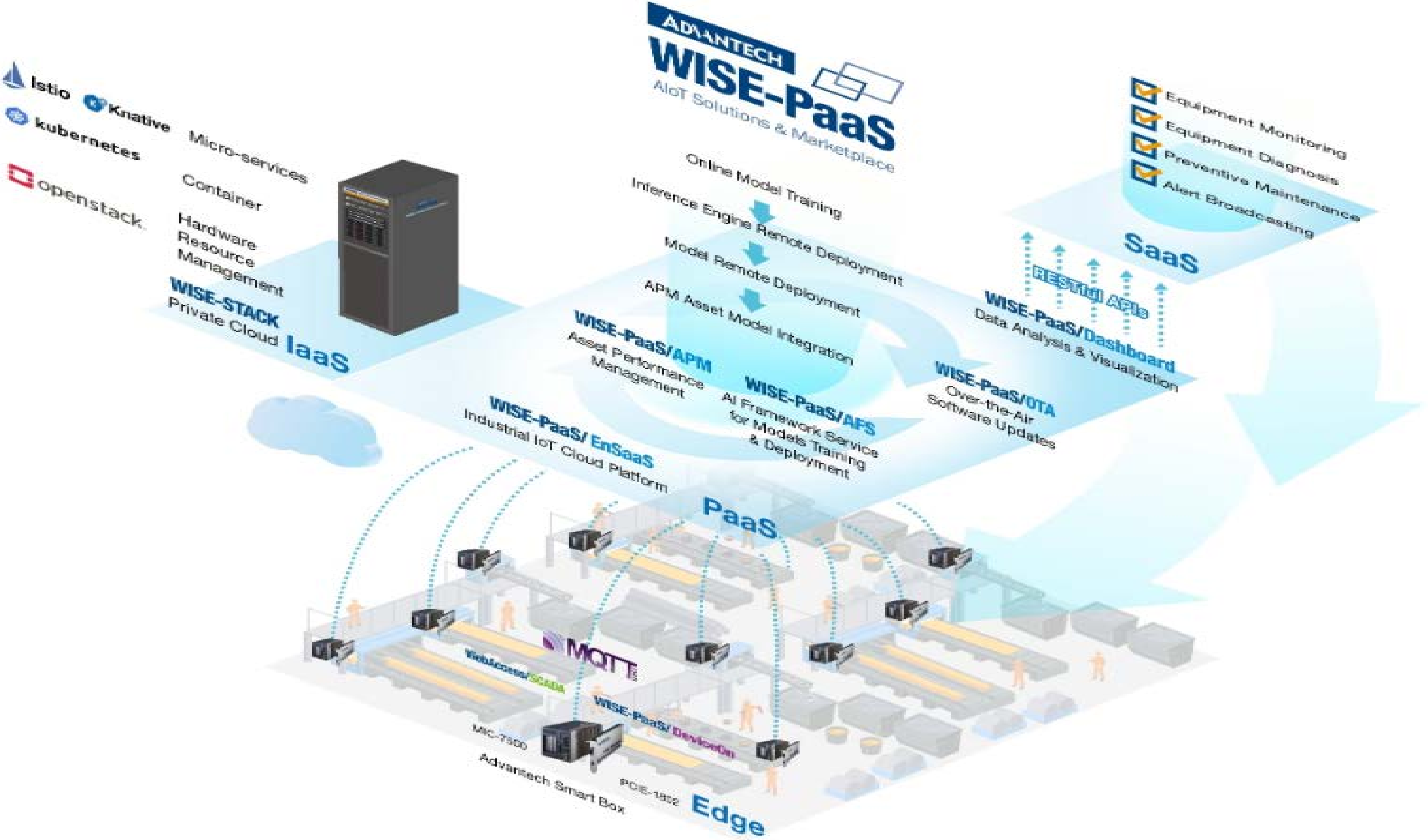
IT	OT
Frequent updates & upgrades running for years	Very few updates; usually installed and left
Interconnected with the internet	Isolated from the Internet
Focus: Privacy, Reliability, Security	Focus: Safety, Reliability, Resilience
Weakness: Resilience	Weakness: Security



Convergence of IT and OT



Convergence of MES and ERP systems


ADVANTECH
WISE-PaaS
AIoT Solutions & Marketplace
Istio
Knative
kubernetes
openstack.
Micro-services
Container
Hardware
Resource
Management
WISE-STACK
Private Cloud
IaaS
Online Model Training
Inference Engine Remote Deployment
Model Remote Deployment
APM Asset Model Integration
WISE-PaaS/APM
Asset Performance
Management
WISE-PaaS/AFS
AI Framework Service
for Models Training
& Deployment
WISE-PaaS/ EnSaaS
Industrial IoT Cloud Platform
WISE-PaaS/OTA
Over-the-Air
Software Updates
WISE-PaaS/Dashboard
Data Analysis & Visualization
RESTful APIs
Equipment Monitoring
Equipment Diagnosis
Preventive Maintenance
Alert Broadcasting
SaaS
PaaS
MQTT
WebAccess/SCADA
WISE-PaaS/ DeviceOn
MIC-7500
Advantech Smart Box
PCIE-1852
Edge

Data
FUYUU TECH
IOT Scada
Monitoring on-line : V 1.5
Control
Connection
Process
Communication
Things

V-NET System Technology Architecture

Cloud architectures

Once a manufacturing company has decided it wants to migrate from an on-premise solution to a cloud-based SCADA/MES application, there are a number of possible architectures to choose from. Traditional SCADA and MES suppliers are starting to offer off-the-shelf cloud-hosted SCADA/MES products, which typically adopt one of the following cloud architectures:

1. Application + Infrastructure-as-a-Service (App + IaaS): Standalone applications running on virtual machines hosted in the cloud.

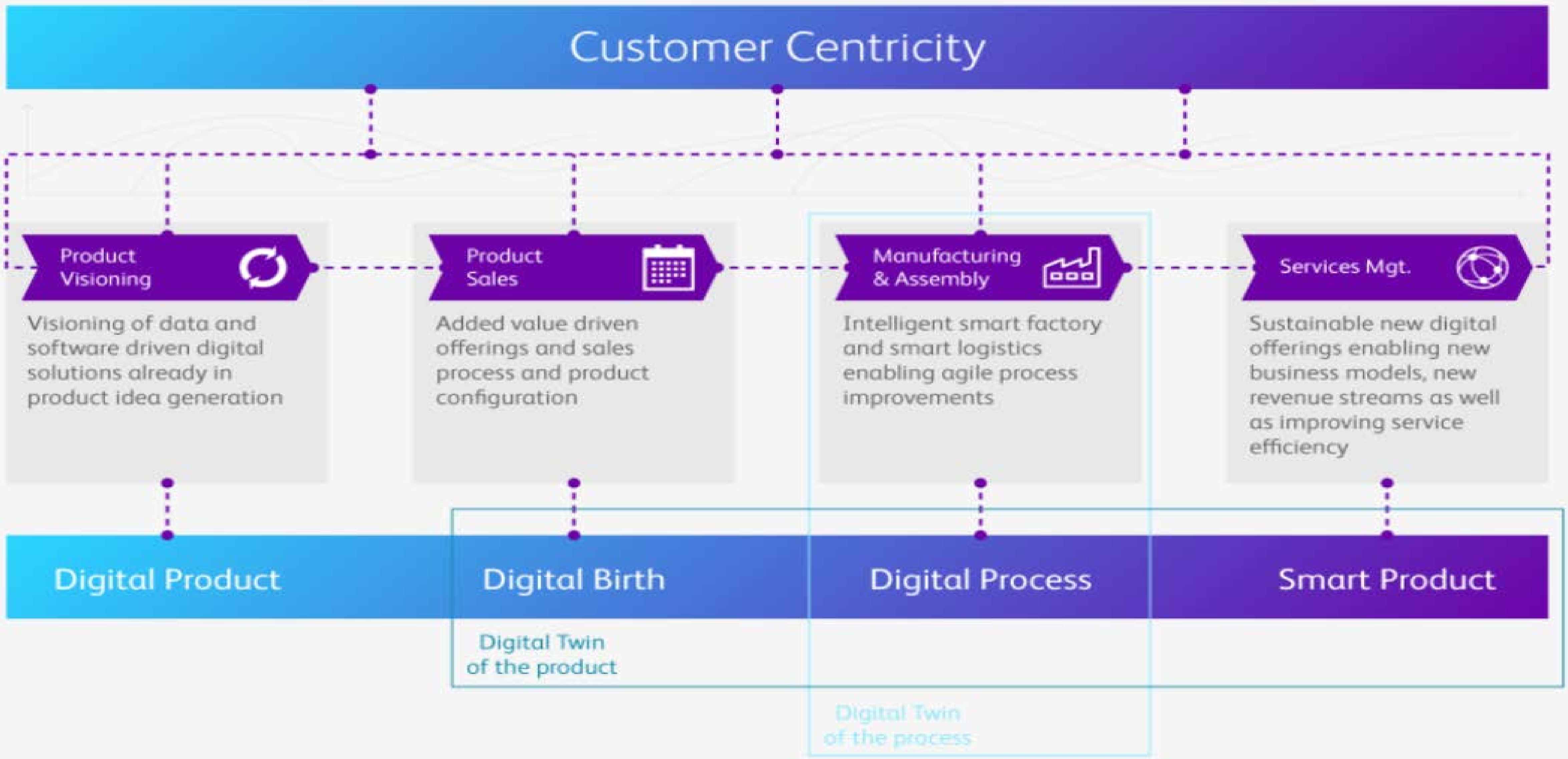
2. Application built on a Platform-as-a-Service (App + PaaS): Applications built on top of and tightly coupled with a particular IoT cloud platform-as-a-service provider like Azure IoT or AWS IoT.

3. Software-as-a-Service (SaaS): Multi-tenant, end-to-end, cloud applications that are not built on top of a PaaS and are hosted on either leased or owned IT infrastructure.

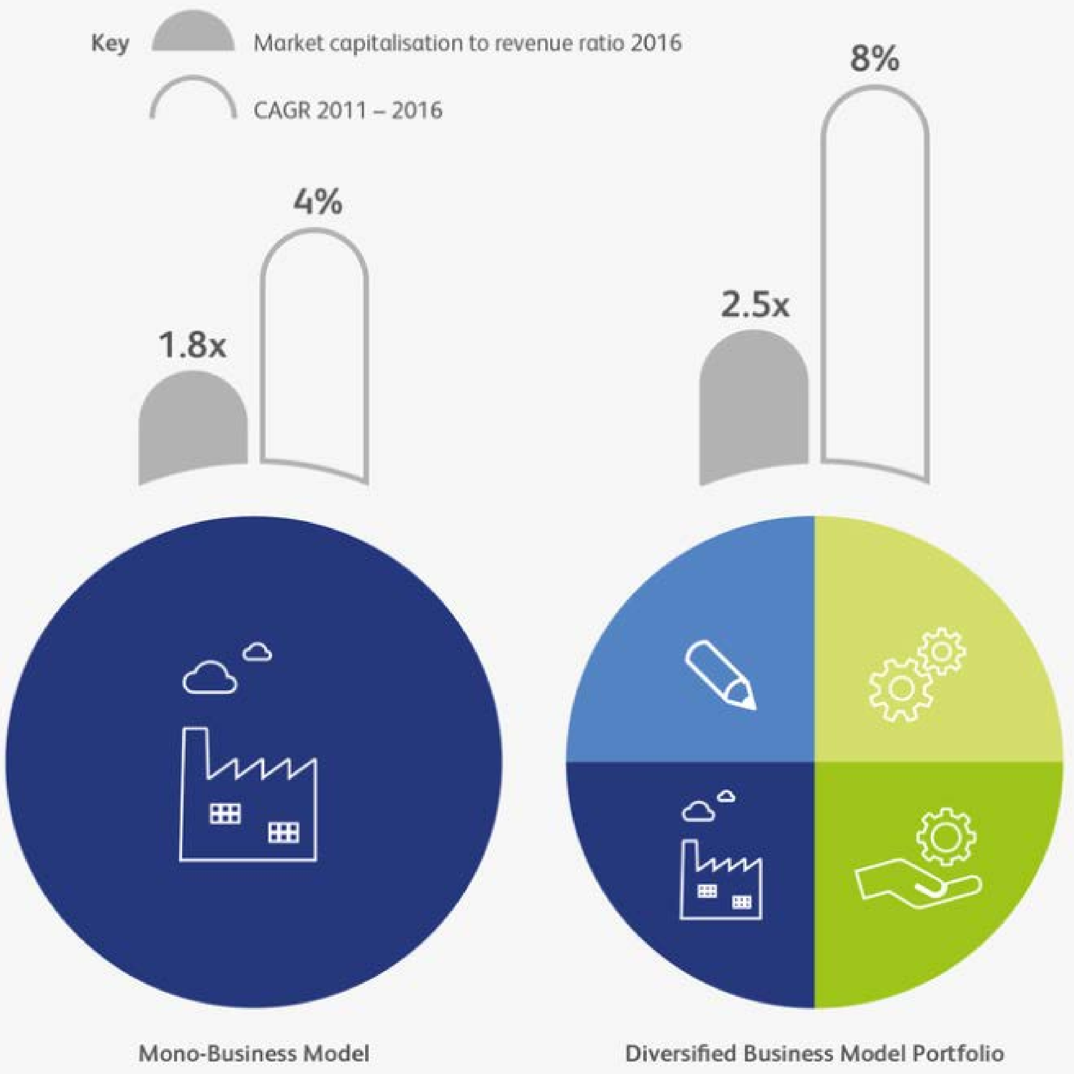
IoT cloud infrastructure and platform as-a-service providers

Microsoft and **Amazon** are the leading providers for Infrastructure-as-a-Service with 13% and 33% of the market share respectively. Not surprisingly, the latest IoT Analytics IoT Platforms Report found that both Microsoft and Amazon were also leaders in the IoT platform space, although Microsoft had a narrow lead over Amazon (29% vs. 28%). Microsoft's history with industrial automation companies dates back to the create of the open platform communications (OPC) industrial communications standard, which at the time of its invention in early 1990s required a Windows 3.0 operating system. The impressive roster of industrial automation companies that have partnered with Microsoft Azure to host their IIoT platforms is a testament to Microsoft's ability to use its existing relationships with industrial automation companies. Azure seems to be emerging as the infrastructure of choice for IIoT end users and industrial automation providers alike.

The big picture for Industry 4.0



Stage of evolution	Get connected	Get insights	Get optimized	Innovate
	connect your assets via the internet and cloud systems - gather and use big data	remotely monitoring your assets enables access to detailed information across the complete lifecycle	enhance and expand your core business with holistic value chain analytics based on gathered data	develop new business models by taking advantage of your existing areas of competence
Enhance this stage	Connected Sensor Kit by BearingPoint for plug & play IoT for retrofit equipment and products	BearingPoint HyperCube providing advanced analytics and Machine Learning for connected dots	BearingPoint Factory Navigator optimizing logistics and manufacturing processes	Predictive Maintenance and Software as a Service (XaaS) to monetarize new business models



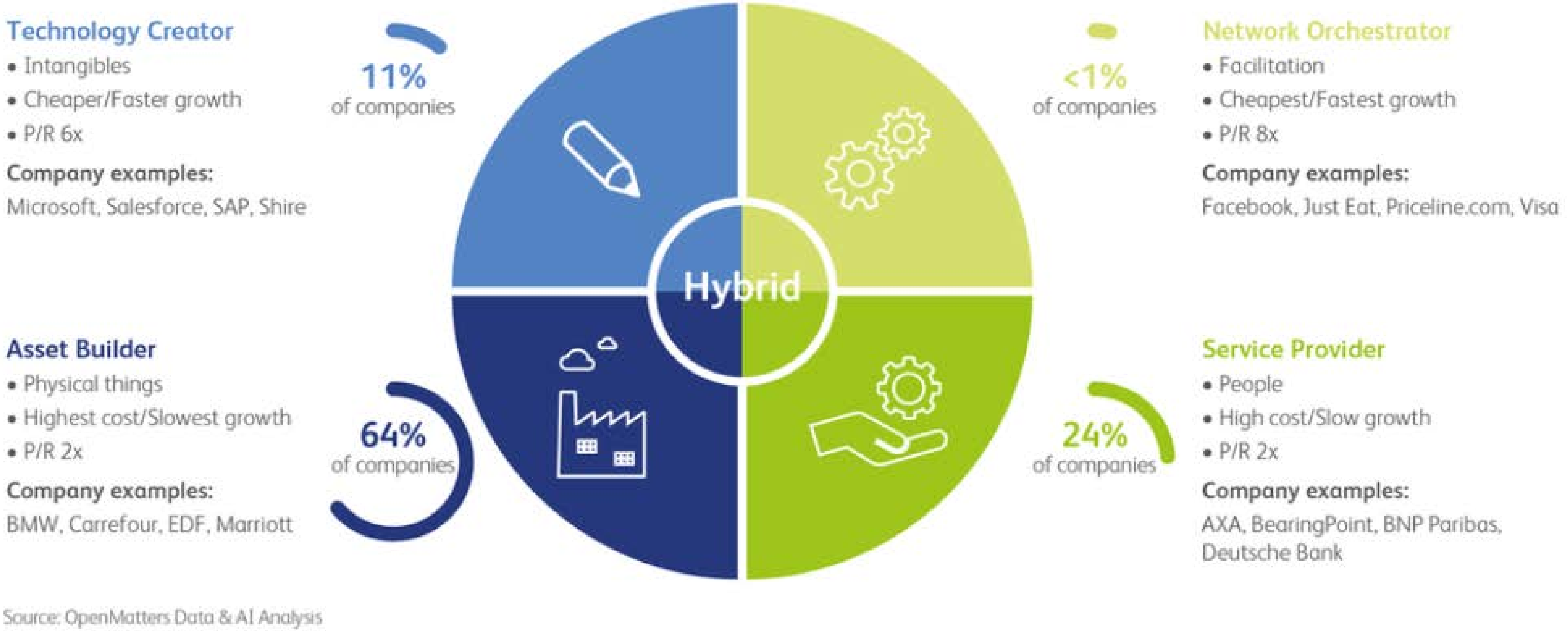
Four primary business models

Asset Builders
Extract, manufacture, distribute or sell physical goods or access to them

Service Providers
Hire and train skilled employees and sell their services

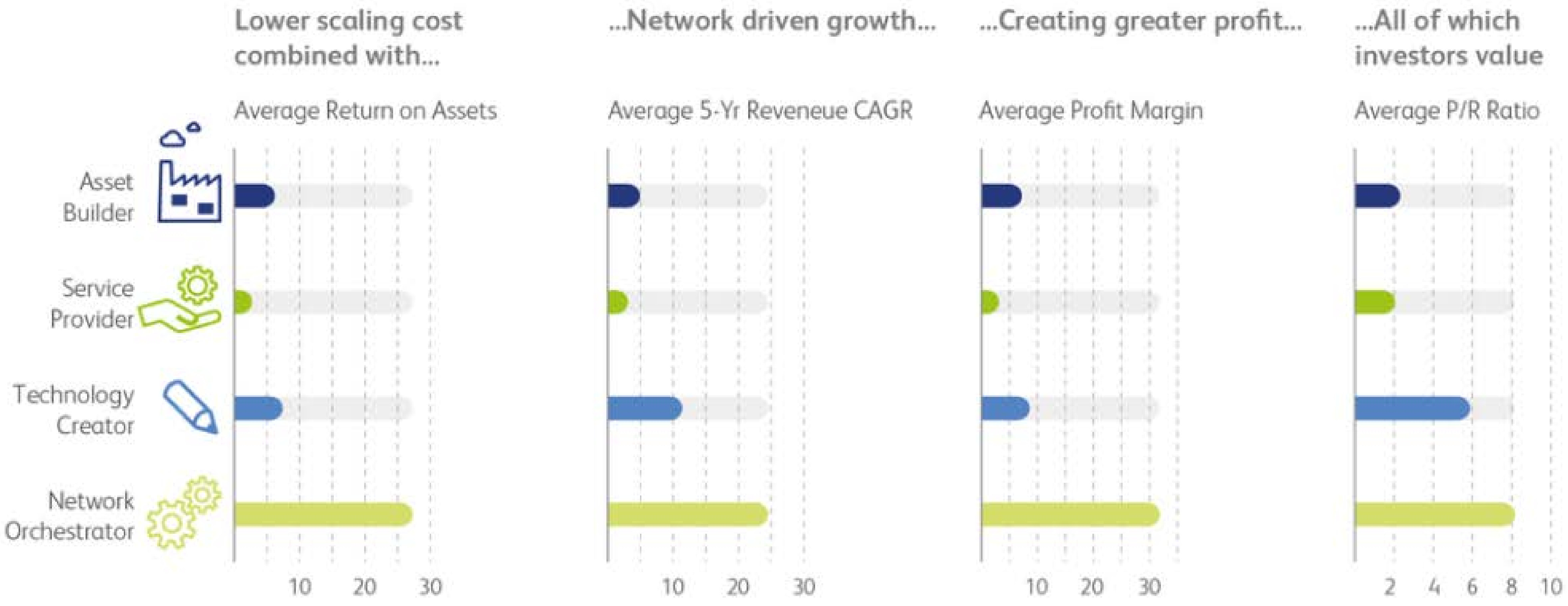
Technology Creators
Develop and protect intellectual capital—often intangible products with low marginal costs of growth, such as software

Network Orchestrators
Create and maintain networks of people, things and information, facilitating interactions and transactions between them



Four primary business models

1. **Asset Builders** extract, manufacture, distribute or sell physical goods or access to them. Manufacturers, retailers and telecom providers fall into this group, which covers about 64% of the sampled companies today.
2. **Service Providers** hire and train skilled employees and sell their services. Banking, insurance, consulting and engineering companies are all service providers. About 24% of companies fit in this category.
3. **Technology Creators** develop and protect intellectual capital—often intangible products with incredibly low marginal costs of growth, such as software for example. In this group are software vendors, data and biotech companies. By their ("virtual") nature, intangibles unlock far greater synergies and savings - a key source of new customer value added. 11% of companies operate this model.
4. **Network Orchestrators** create and maintain networks of people, things and information, facilitating interactions and transactions between them. Fewer than 1% of companies incorporate this model.



P/R ratio: market capitalization to revenue ratio
Source: OpenMatters Data & AI Analysis

Network Orchestrators outperform other business model types on all measures

Pure-play Network Orchestrators are seeing two to four times higher market valuations and market capitalization growth at around 200%

So, should all organizations become pure-play Network Orchestrators? The answer is no, even if this were possible. While many traditional organizations operate a single business model, the vast majority being Asset Builders, many others combine complementary business model types. For example:

- Most pharmaceutical companies develop new drugs (Technology Creator) and manufacture those drugs (Asset Builder).
- Most automotive companies make cars (Asset Builder), provide captive finance and insurance (Service Provider) and are increasingly providing new digital services (Technology Creator).

Source: OpenMatters Data & AI Analysis

Business model breakdown of most successful companies over the last 15 years

Learn from European success stories across vertical sectors

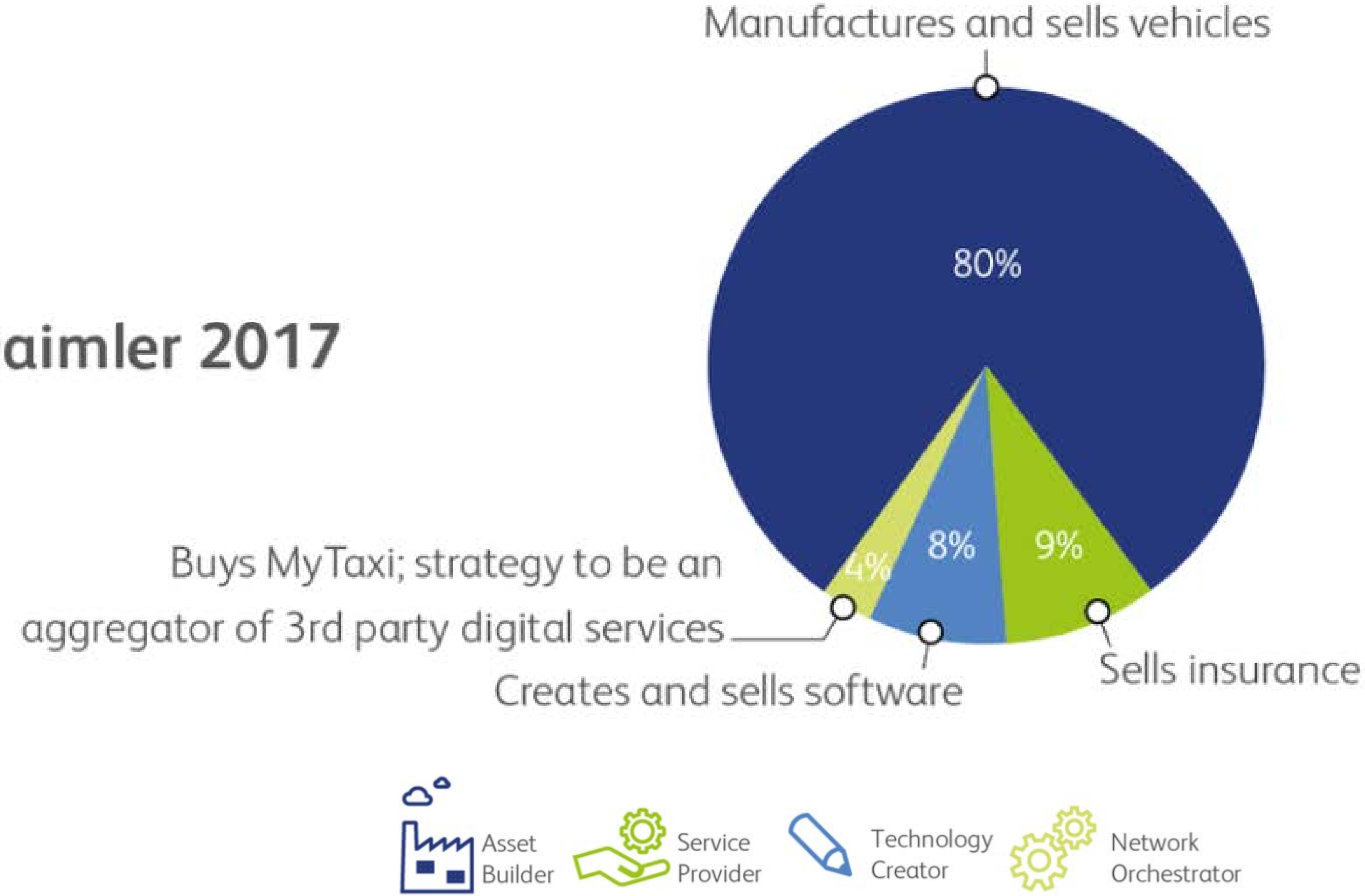
To build successful business models incorporating network orchestration, organizations need to manage and leverage the power of their respective ecosystems in their multi-sided value chain, not for their own sake but because it makes good, financial business sense. So, how do European companies fare?

To determine the effectiveness of each business model over time, and to provide direction on how European organizations can evolve to a better mix, we applied OpenMatters' machine learning algorithm to the S&P and EuroStoxx 500 Index companies, running the analysis from 2010 to now. From the findings we can see European sectors are evolving at different speeds. Very few incumbent business model innovators exist today in Europe: Schibsted, Zalando, and SAP are part of a very small set of Top 500 European companies who are evolving significantly.

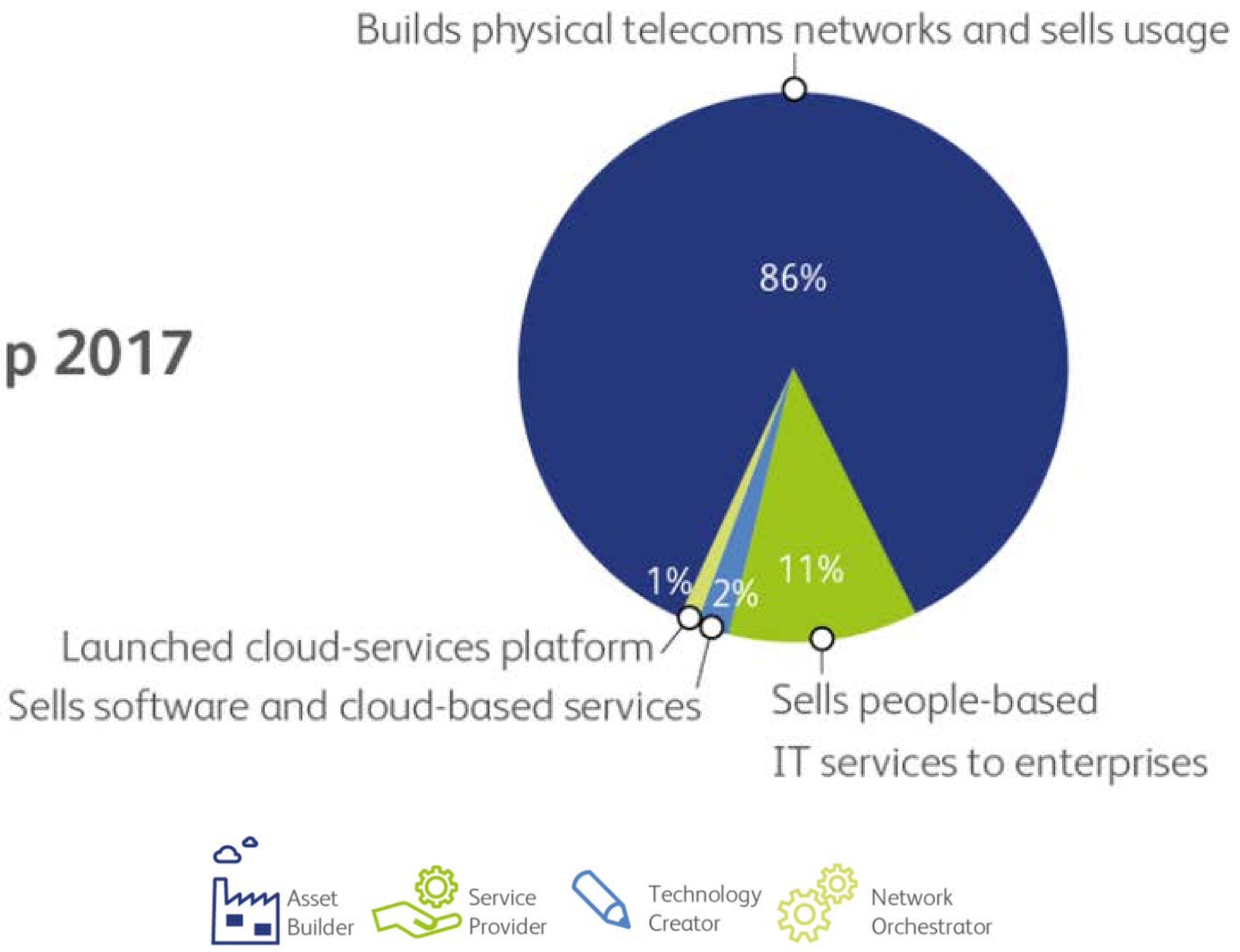
All the same, some European incumbents are investing in more dynamic business model portfolios, incorporating Technology Creator and Network Orchestrator elements. Most automotive companies have about 1% Network Orchestrator with Daimler, a leader, at 4%. In more traditional sectors, like telco and financial services, the levels are around 1% at best.

Within each sector are companies who have combined business models to address specific needs and contexts. This means they are adapting to the digital economy by increasing the synergies across their existing businesses. This translates into growth and higher profit margins through better differentiation, more satisfied customers, greater efficiency and higher return on capital employed.

Daimler 2017



BT Group 2017



Industrial B2B

Manufacturing organizations have made significant moves towards incorporating network orchestration. Bosch and Schneider Electric have been proactive in creating and enabling IoT services for example, and Siemens has committed to become a 'digital industrial company', including training and organizational re-design. German firm Klöckner has unveiled a bold strategy to not only create a digital platform for its own services, but also open it up to third parties and competitors. (note 3)

Media

Most media companies face significant threats to their core business model of advertising-funded broadcasting and content production. In a bold response to the threat of digital-first competition, German independent ProSiebenSat.1 decided to add digital commerce and online marketplaces into its mix, extending its competence in attracting and monetizing large consumer audiences. (note 4) Meanwhile print media companies Schibsted in Norway and Naspers in South Africa have pivoted their business models to include network orchestration, with a portfolio of online marketplaces, portals, auction and classified sites. Schibsted achieved record operating profits in 2017 and Naspers continues to grow at nearly 20-30% per annum. (note 5)

Retail

An increasing number of European retailers have started to adopt Network Orchestration. French electronics retailer Darty introduced a third-party marketplace in 2014, dramatically increasing the choice of goods it can now offer its customers, significantly grown traffic to its website, and has benefited from twice the margin on goods sold through the market compared with its traditional business. (note 6) And Zalando, a successful European e-commerce site focused on fashion and clothes recently incorporated network orchestration into its mix by opening up its digital platform to third-parties. (note 7)

Hospitality

The hospitality industry is waking up to its network orchestration role. In a bold move to catch up, Accor invested heavily in network orchestration, opening up its booking system to third parties, acquiring the room rental marketplace OneFineStay and concierge service provider John Paul. (note 8) In a bid to change their culture, it created a 'shadow board' of employees less than 30 years old who make recommendations on how to be more digital. Other hotel chains are following a similar acquisition strategy, with Wyndham Worldwide buying LoveHomeSwap in 2017. (note 9)

Automotive

The major automotive manufacturers have started to embrace network orchestration by investing in or buying service orientated digital business platforms, ride-sharing and ride-hailing businesses. Very sensibly some have established separate business units to run these activities with operating models, metrics and staff – for example, Daimler's Moovel Group and Volkswagen's MOIA. (note 10) However, we now see a proliferation of competing services which are unlikely to have the scale needed to succeed. Recent talk about greater industry-wide collaboration and potentially merging certain digital operations makes a lot of sense.

Telecoms

We can see several examples of network orchestration success in telecoms. For example Nordic Telenor invested in online classifieds businesses as part of its new digital strategy, and BT Global Services created a highly innovative cloud services platform (note 11) but these are exceptions. Telco talks about an enterprise IoT opportunity, but focuses on connectivity rather than ecosystem-enabling platforms. So there is work to be done. (note 12)

Retail Banking

European banks are beginning to understand the role of network orchestration, forced partly by open banking regulation ("PSD2"). Leaders such as ING Group are talking of plans to stay relevant by creating digital business platform-powered ecosystems of 'beyond banking' third party services. (note 13) Deutsche Bank recently and impressively applied platform thinking and network orchestration, bringing to market a multi-bank aggregation service and a retail deposit marketplace, and leading the establishment of the Verimi pan-European cross-sector digital identity scheme. (note 14) Fintech and digital masters like Alibaba continue to target high margin retail banking services with low levels of business model reinvention, such as Alipay for online and mobile payments.

Insurance

Ping An from China last year took this accolade due to the success of its digital ecosystem management strategy which is enabling it to stay more central to customers lives by leveraging others. Indeed Ping An positions itself as 'technology company with financial services licenses'. (note 15)

Non-public start-up companies

Many examples of successful network orchestration come from start-ups who think differently about how to serve markets. One example is Houzz, an online platform for connecting home owners with professionals for interior design and other household improvements. Started in 2009, it now has 40 million monthly average users globally and is valued at $4bn, offering what some see as a combination of Pinterest, Yelp, Amazon and Task Rabbit. (note 16)

Source: OpenMatters Data & AI Analysis

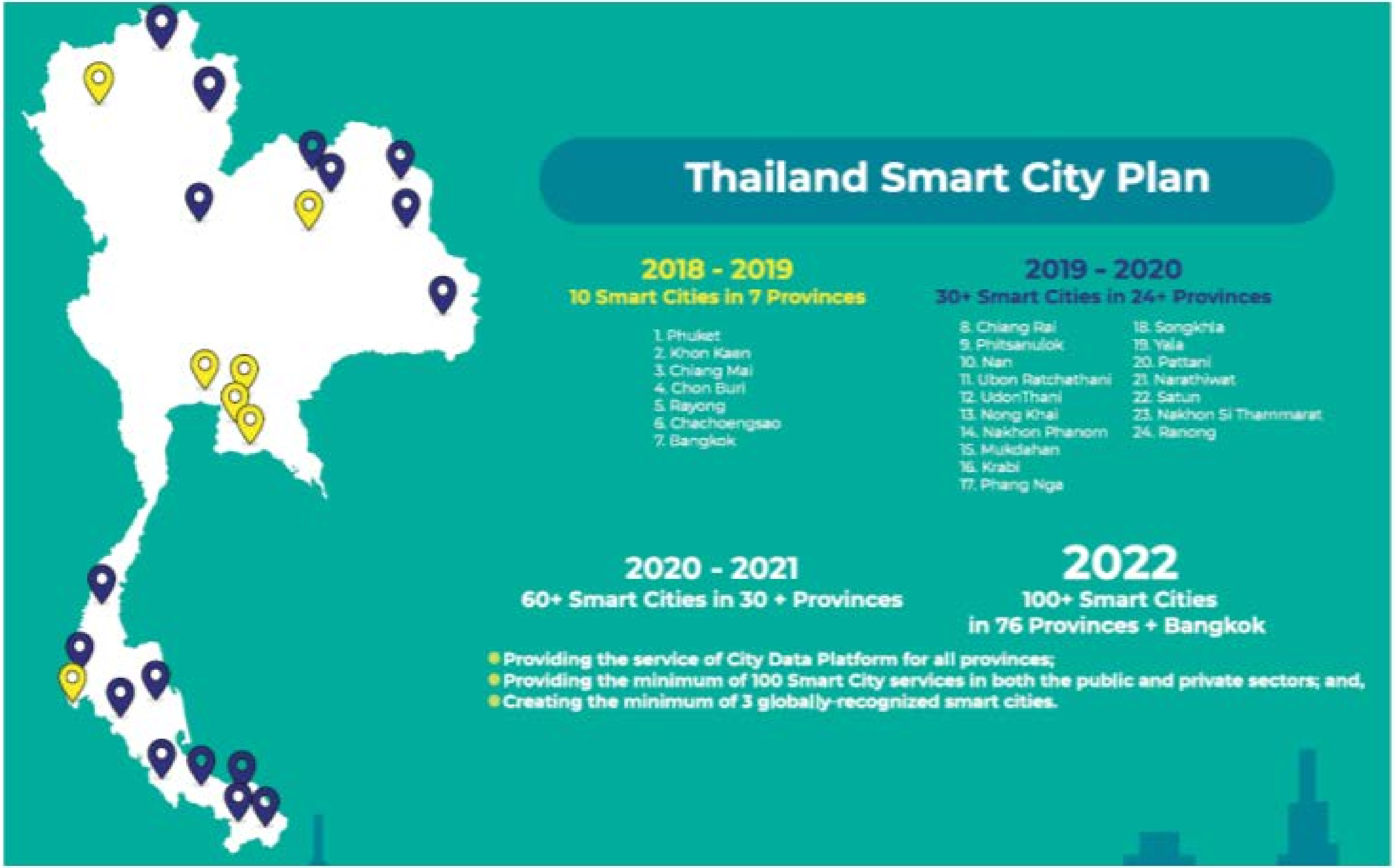
How you think, drives where you spend, drives what you measure, and what you get

ประเทศไทย 4.0

Source: Asia IoT Business Platform

Global Smart City Development

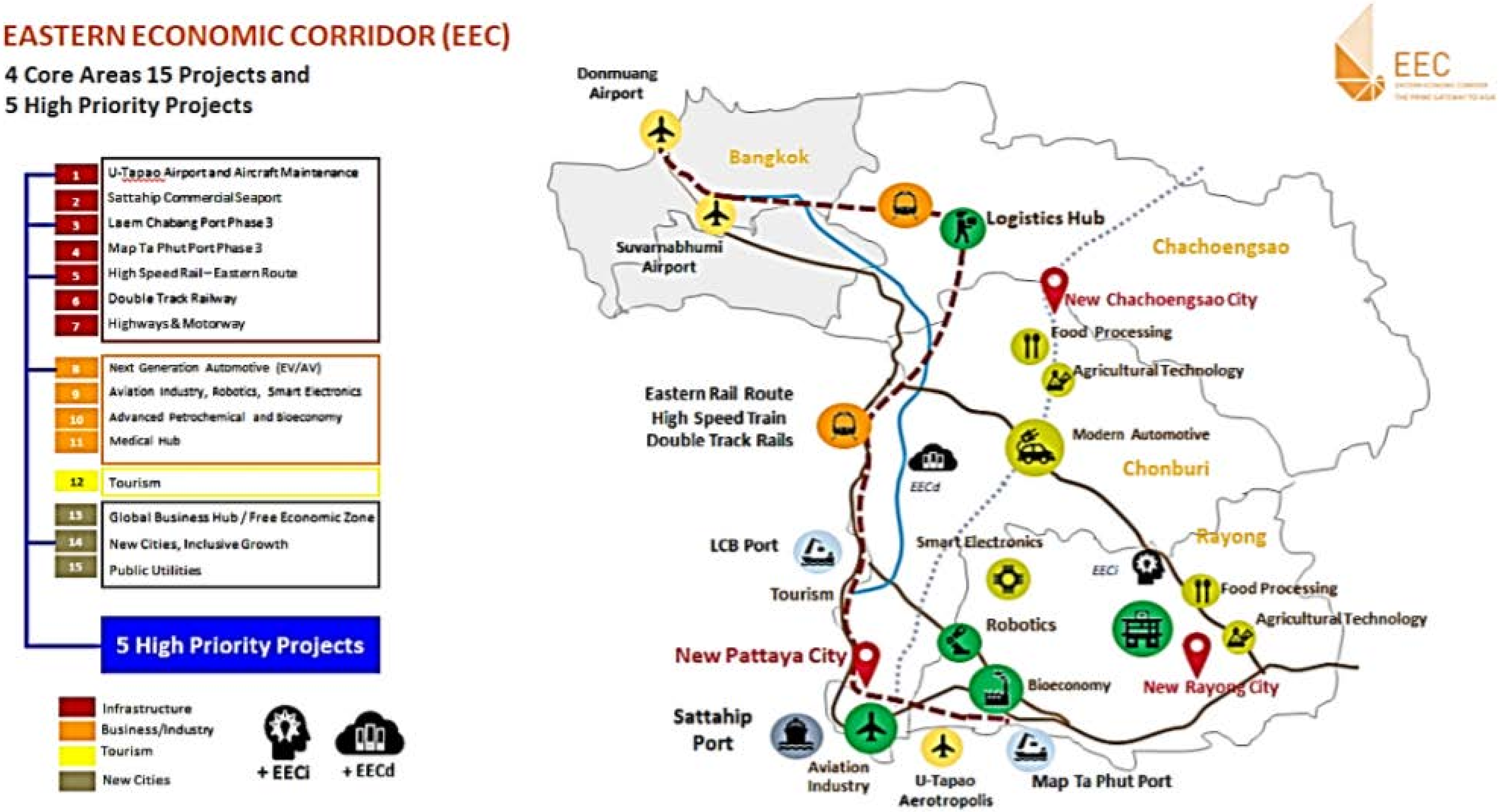
Source Frost & Sullivan



Source: Smart City Thailand Office

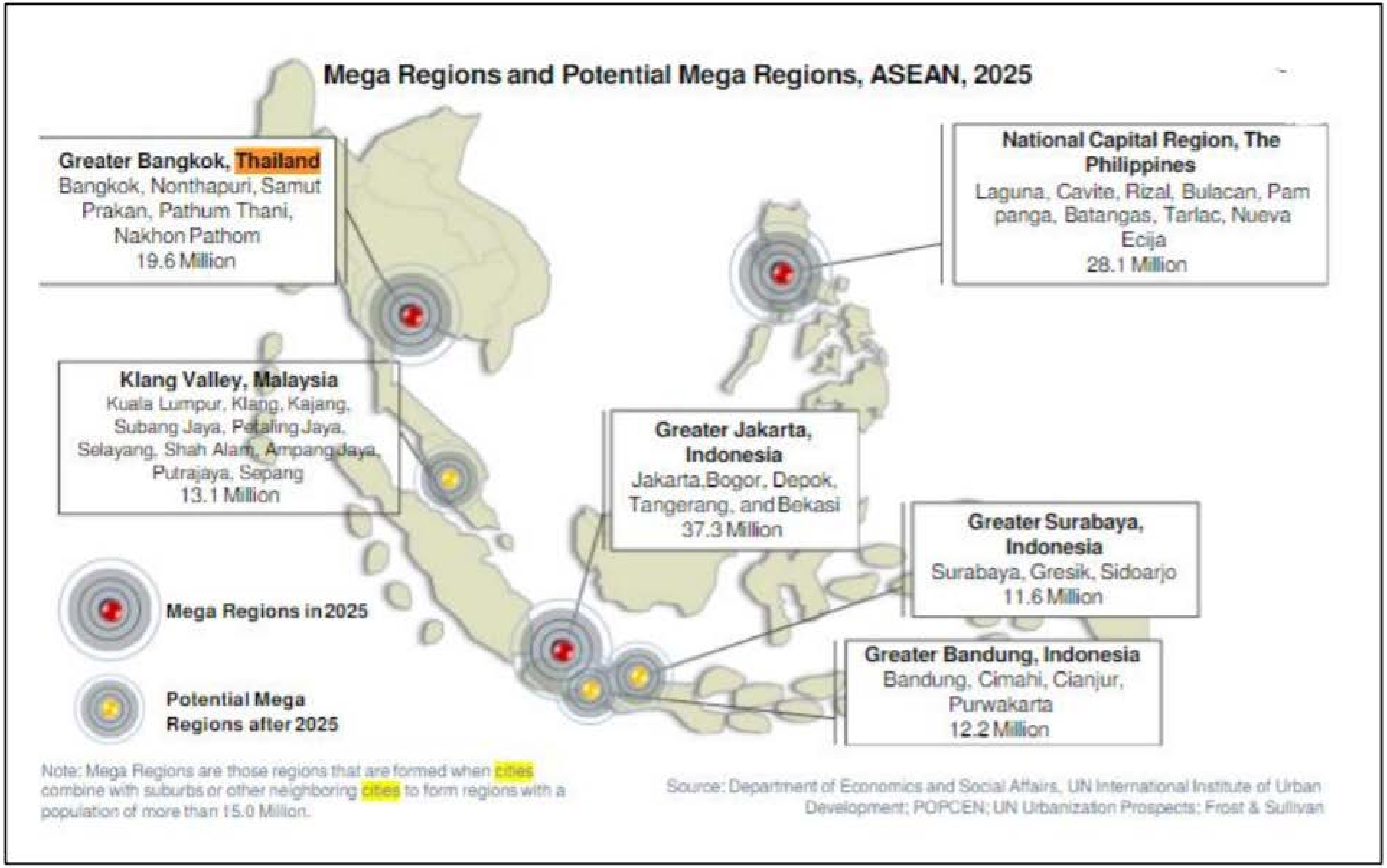
Source: Smart City Thailand Office

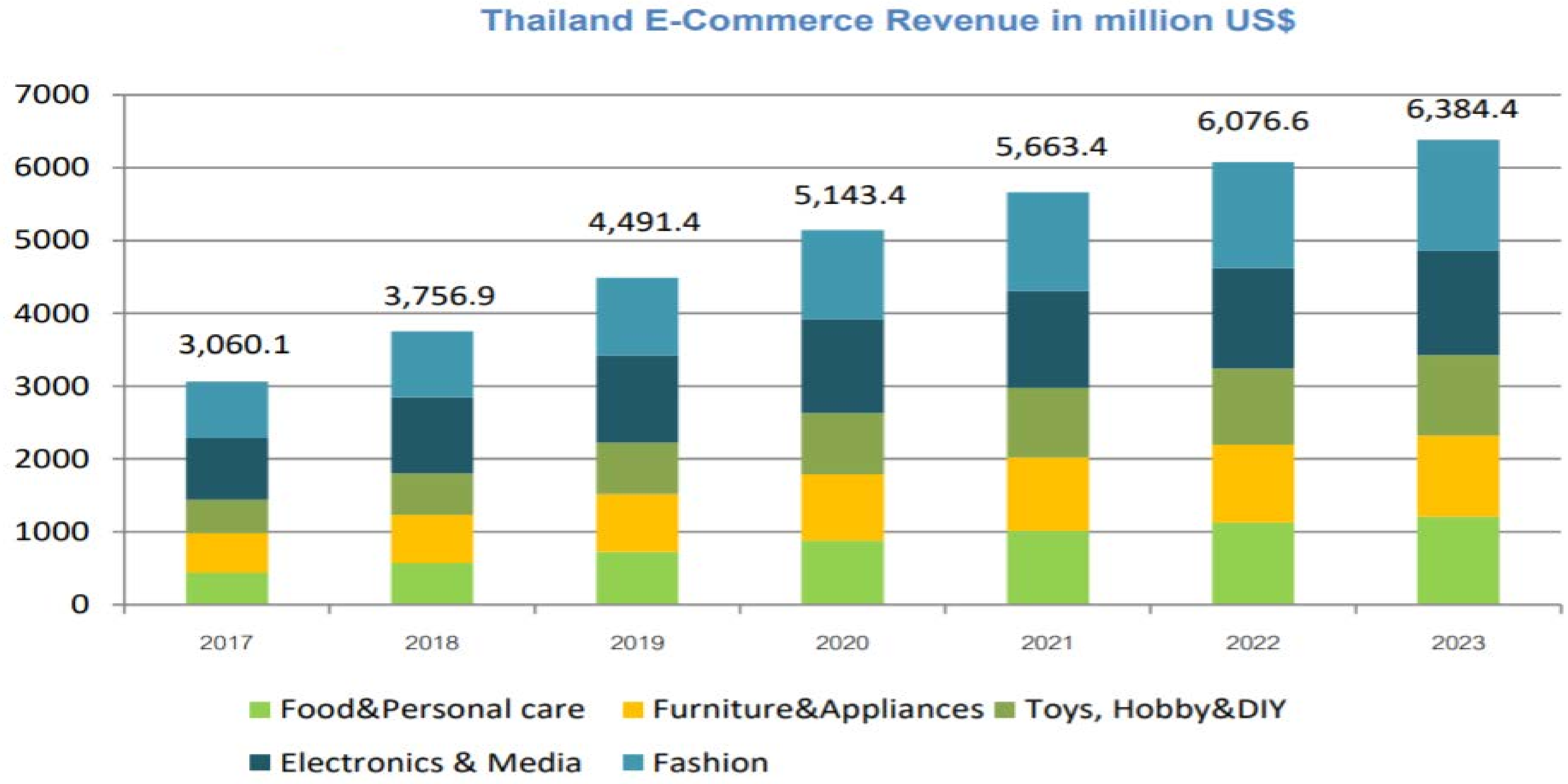
Smart City Phase 2 as part of the Eastern Economic Corridor (EEC)



Source: Thailand Eastern Economic Corridor (EEC)


Smart City Spotlight: Bangkok
Bangkok's smart city potential
Primary business centre in Thailand
One Bangkok, fully integrated district built on people-centric principles with a focus on environmental sustainability and smart city living
Expanding urban transportation network
Hotspot for green investments
Growing urban literate population


Mega Regions and Potential Mega Regions, ASEAN, 2025
Greater Bangkok, Thailand
Bangkok, Nonthapuri, Samut Prakan, Pathum Thani, Nakhon Pathom
19.6 Million
National Capital Region, The Philippines
Laguna, Cavite, Rizal, Bulacan, Pam panga, Batangas, Tarlac, Nueva Ecija
28.1 Million
Klang Valley, Malaysia
Kuala Lumpur, Klang, Kajang, Subang Jaya, Petaling Jaya, Selayang, Shah Alam, Ampang Jaya, Putrajaya, Sepang
13.1 Million
Greater Jakarta, Indonesia
Jakarta,Bogor, Depok, Tangerang, and Bekasi
37.3 Million
Greater Surabaya, Indonesia
Surabaya, Gresik, Sidoarjo
11.6 Million
Greater Bandung, Indonesia
Bandung, Cimahi, Cianjur, Purwakarta
12.2 Million
Mega Regions in 2025
Potential Mega Regions after 2025
Note: Mega Regions are those regions that are formed when cities combine with suburbs or other neighboring cities to form regions with a population of more than 15.0 Million.
Source: Department of Economics and Social Affairs, UN International Institute of Urban Development; POPCEN; UN Urbanization Prospects; Frost & Sullivan



Source: Statista, October 2018

Thailand transition to cashless economy

Source: appsyth

Thailand's Digital Economy

ICT 2020


รัฐบาลดิจิทัล ....ก้าวสำคัญของประเทศไทย 4.0
รัฐบาลอิเล็กทรอนิกส์ สู่ รัฐบาลดิจิทัล
แผนพัฒนา
รัฐบาลดิจิทัล
ระยะ 3 ปี มี 6
ขั้นตอนหลัก ดังนี้
1
2
3
4
5
6
"...นิยามของรัฐบาลดิจิทัลได้ขยายขอบเขตมากยิ่งขึ้น
ก้าวไปถึงทำอย่างไรจะให้ประชาชนที่มีคอมพิวเตอร์ในมือ
มีส่วนร่วมในการปฏิสัมพันธ์กับภาครัฐด้วยตนเอง
โดยปลดล็อกข้อจำกัดที่ว่าข้อมูลข่าวสารจาก
ภาครัฐในอดีตยากต่อการเข้าใช้ ให้สามารถเข้าถึง
ได้ง่ายขึ้น สะดวกขึ้น และที่ดีกว่านั้น นำไปต่อยอด
ใช้งานได้ทันที รัฐบาลดิจิทัลไม่มองประชาชนเป็นเพียงผู้ใช้งาน
แต่เป็นส่วนหนึ่งของระบบ ก้าวไปอีกระดับ
นั่นคือระดับที่เป็นการทำงานร่วมกัน..."
ดร. ศักดิ์ เสกขุนทด
ผู้อำนวยการ
สำนักงานรัฐบาลอิเล็กทรอนิกส์
(องค์การมหาชน) (สรอ.)
EGA
e-Government Agency

BENEFITS OF A DIGITAL ECONOMY

The benefits of the government's plan to build a Digital Economy for Thailand and the Thai people include the following areas:

GDP Growth and National Income

10% increase in broadband penetration raises economic growth **by 1.38 %**

75% of the economic benefits of the Digital Economy to date have been captured by traditional industries who are leveraging ICT to create efficiencies and competitive advantages. (BCG)

Competitiveness and Growth

SMEs who heavily use ICT grow and export twice as much as their **competitors**

21% of GDP growth in advanced economies between 2005 and 2010 arose from the Internet and associated digital technologies, doubling its contribution from the previous 10 years. (McKinsey Global Institute)

Labour Productivity and Employment

The global Digital Economy has created 2.4 new jobs for each one lost to technology-related efficiencies

Cheaper broadband is correlated to higher growth rates in labour productivity especially in lower-income OECD countries. (McKinsey, BCG)

Socioeconomic Welfare

In only 15 years the Digital Economy Revolution in developed countries has achieved a rise in GDP per capita equal to what the Industrial Revolution took 50 years to achieve

Broadband encourages equitable access to Education, Government & Health services.

Source Box: [1]Royal Thai Government Statement, "Issues of Priority: Digital Economy"

TARGETS FOR DIGITAL THAILAND

The ICT Ministry's draft Development Plan for Economy and Digital Society 2016 has set out a number of key targets and indicators for the development of a Digital Economy and Society in the near term:[2]

CREATE OPPORTUNITY AND SOCIAL EQUALITY

100%
OF THAI POPULATION
with access to the internet as a standard public service

INCREASE GLOBAL COMPETITIVENESS

25%
OF GDP FROM DIGITAL INDUSTRIES

TRANSFORM GOVERNMENT SECTOR

Top 50 on UN e-Government ranking
(currently 102 of 193)[3]

DEVELOP HUMAN CAPITAL SUPPORT FOR A DIGITAL WORLD

100%
OF THAIS DIGITALLY LITERATE

Source Box:

[2] Ministry of Information and Communication Technology, Development Plan for Economy and Digital Society, draft as of 2 February, 2016

[3] United Nations, United Nations E-Government Survey, https://publicadministration.un.org/egovkb/en-us/Data/Country-Information/id/169-Thailand

HOW IS THAILAND DOING?

KEY INDICATORS IN A REGIONAL COMPARISON: [6]

Country	ICT Development	Global IDI[7] Ranking	Total Mobile Penetration	Unique Mobile Subscribers	3G + 4G	Smartphone
Thailand	4.8	74	122%	85.47%	82.47%	58.98%
Indonesia	3.8	108	126%	58.43%	40.48%	40.37%
Singapore	7.9	19	145%	71.52%	63.14%	78.16%
Malaysia	5.2	64	142%	76.1%	60.3%	64.63%
Philippines	4.0	98	117%	65.09%	44.74%	40.9%
Vietnam	4.1	102	152%	49.66%	36.48%	27.84%

Source Box:

[4] ITU, ITU ICT Development Index, http://www.itu.int/net4/ITU-D/idi/2015/#idi2015rank-tab

[5] Global Web Index, Thailand Market Report 2015

[6] Data from ITU, 2015; GSMA Intelligence, Q4 2015

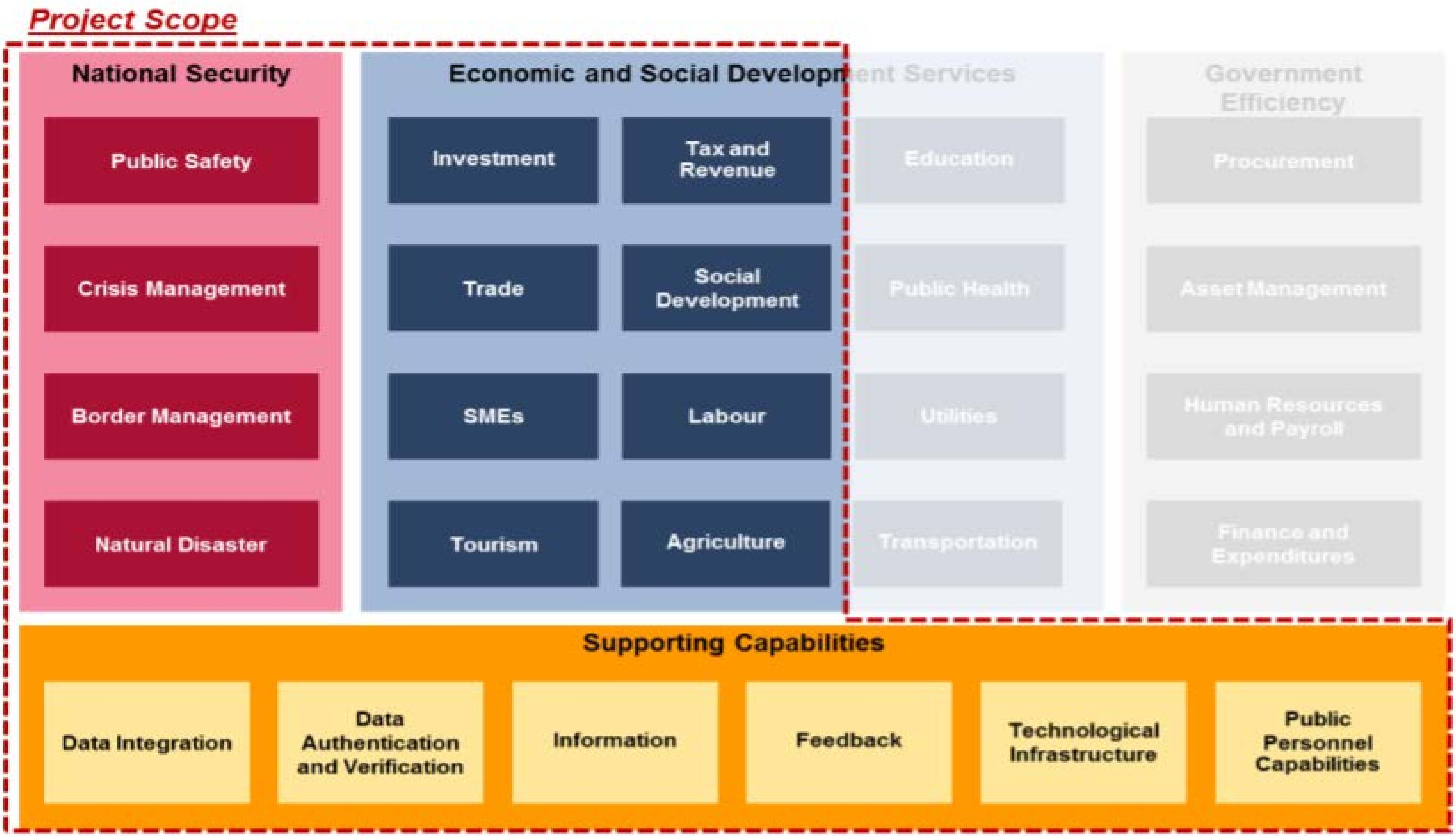
[7] IDI, ICT Development Index

Strategy 1: National Security includes Public Safety, Border Management, Natural Disaster and Crisis Management

Strategy 2: Economic and Social Development Services includes Investment, Trade (Imports and Exports), Small and Medium Enterprises (SMEs), Tourism, Tax and Revenue, Labour, Agriculture, Social Development, Education, Public Health, Utilities and Transportation

Strategy 3 Government Efficiency includes Procurement, Asset Management, Human Resources and Payroll and Finance and Expenditures

Strategy 4 Supporting Capabilities includes Information, Feedback, Data Integration, Data Authentication and Verification, Technological Infrastructure and Public Personnel Capabilities


Project Scope
National Security
Public Safety
Crisis Management
Border Management
Natural Disaster
Economic and Social Developm
ent Services
Government Efficiency
Investment
Tax and Revenue
Trade
Social Development
SMEs
Labour
Tourism
Agriculture
Education
Public Health
Utilities
Transportation
Procurement
Asset Management
Human Resources and Payroll
Finance and Expenditures
Supporting Capabilities
Data Integration
Data Authentication and Verification
Information
Feedback
Technological Infrastructure
Public Personnel Capabilities

4 Strategies in Developing a Digital Government

Strategy 1

Developing the capacity to support government services

- **Data Integration:** Central Data Sharing Platform
- **Data Authentication and Verification:** Biometrics & Single Electronic User Account for Authentication
- **Information:** Customer Centric Information Portal
- **Feedback:** Proactive Integrated Case Management System
- **Technological Service Infrastructure**
- **Public Personnel Capabilities**

Strategy 2

Elevation of Citizen's Quality of Life

- **Social Development:** Integrated & Proactive Social Service
- **Labour:** Integrated Virtual Labour Market

Strategy 3

Enhancing the capacity of the business sector's competitiveness

- **Agriculture:** Connected Farmer with Real Time Analytics
- **Tourism:** Digital Tourism
- **Investment:** Integrated Business Licensing System
- **Trade (Imports & Exports):** Trade Single Window (B2B & B2G)
- **SMEs:** Integrated & Proactive SME Support
- **Tax and Revenue:** Integrated Tax System

Strategy 4

Increasing national security and public safety

- **Public Safety:** Proactive Public Safety
- **Border Management:** Integrated & Automated Border Management
- **Natural Disaster:** Natural Disaster Management Driven by Scenario-Based Simulations
- **Crisis Management:** Integrated Crisis Management Practices

The 18 Digital Capabilities are aligned under 4 ‘Development Visions’

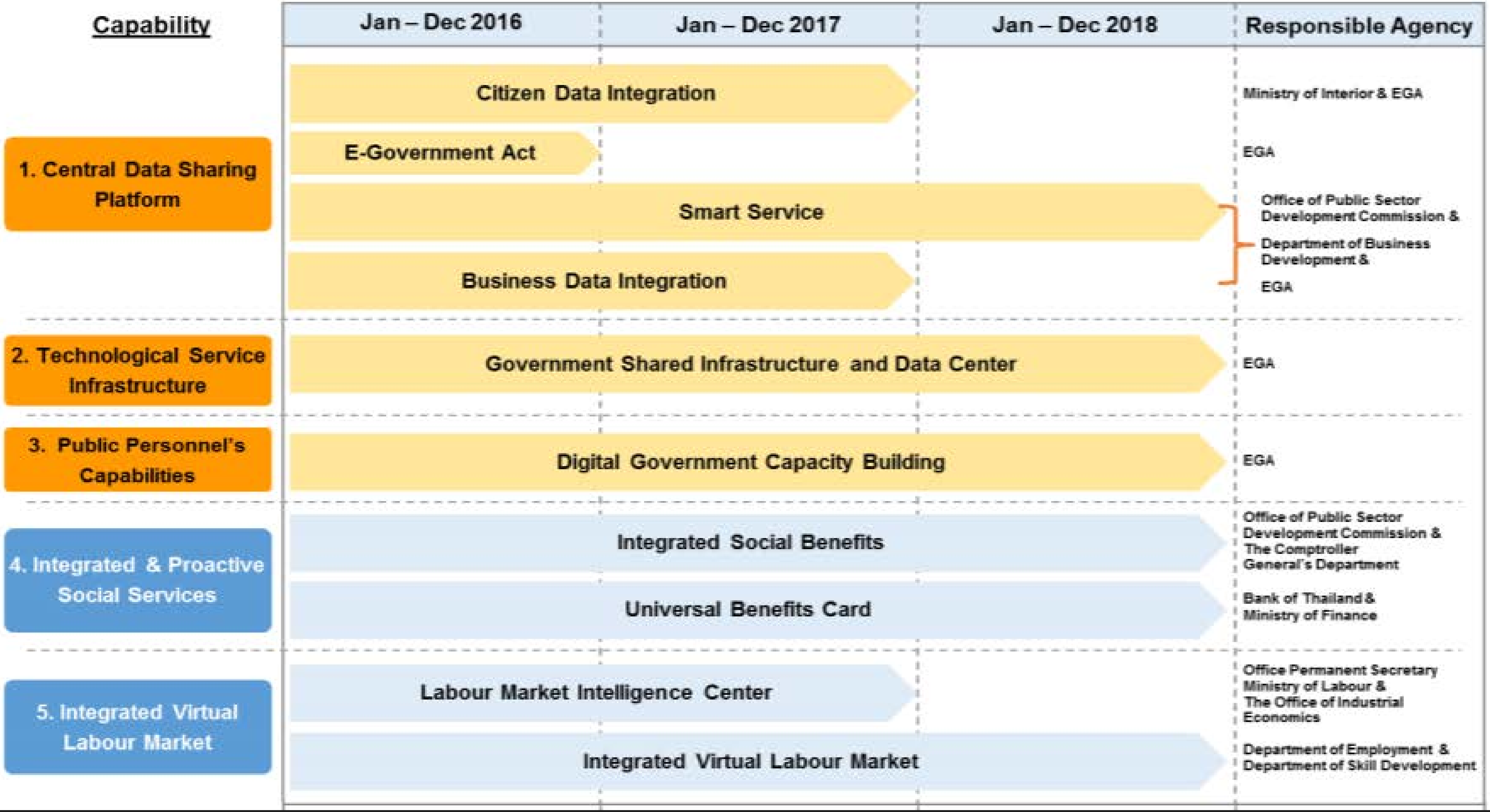
Vision 1 Government Integration: Integration between different agencies including information and operations integration in order to provide a single complete view of a citizen, shared services, and integrated government services at a single point.

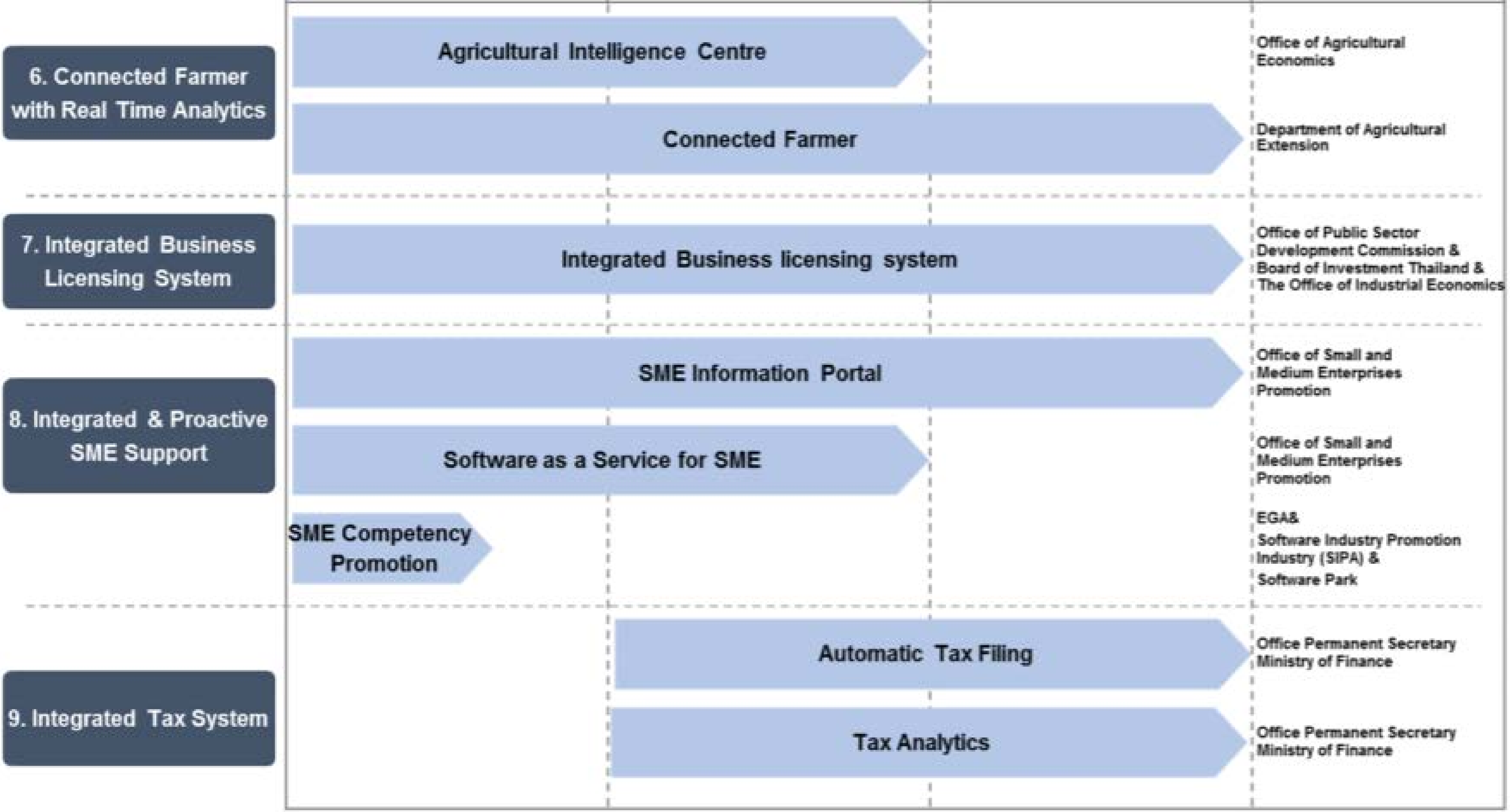
Vision 2 Smart Operations: Utilizing technology and digital equipment in supporting personnel’s work tasks by connecting between equipment, supporting the management of Big Data and leveraging analytic tools (Internet of Things).

Vision 3 Citizen-centric Services: Elevating the services sector so that there is personalized experience that provides service based on an individual’s needs.

Vision 4 Driven Transformation: Changing an organization in aspects such as human resources, work processes, technology and regulations through an ‘Outcome-driven Transformation’ philosophy. In addition, an organization should receive full support from leaders with determination, vision and sees the importance in utilizing technology to trigger an ‘End-to-End Transformation.’

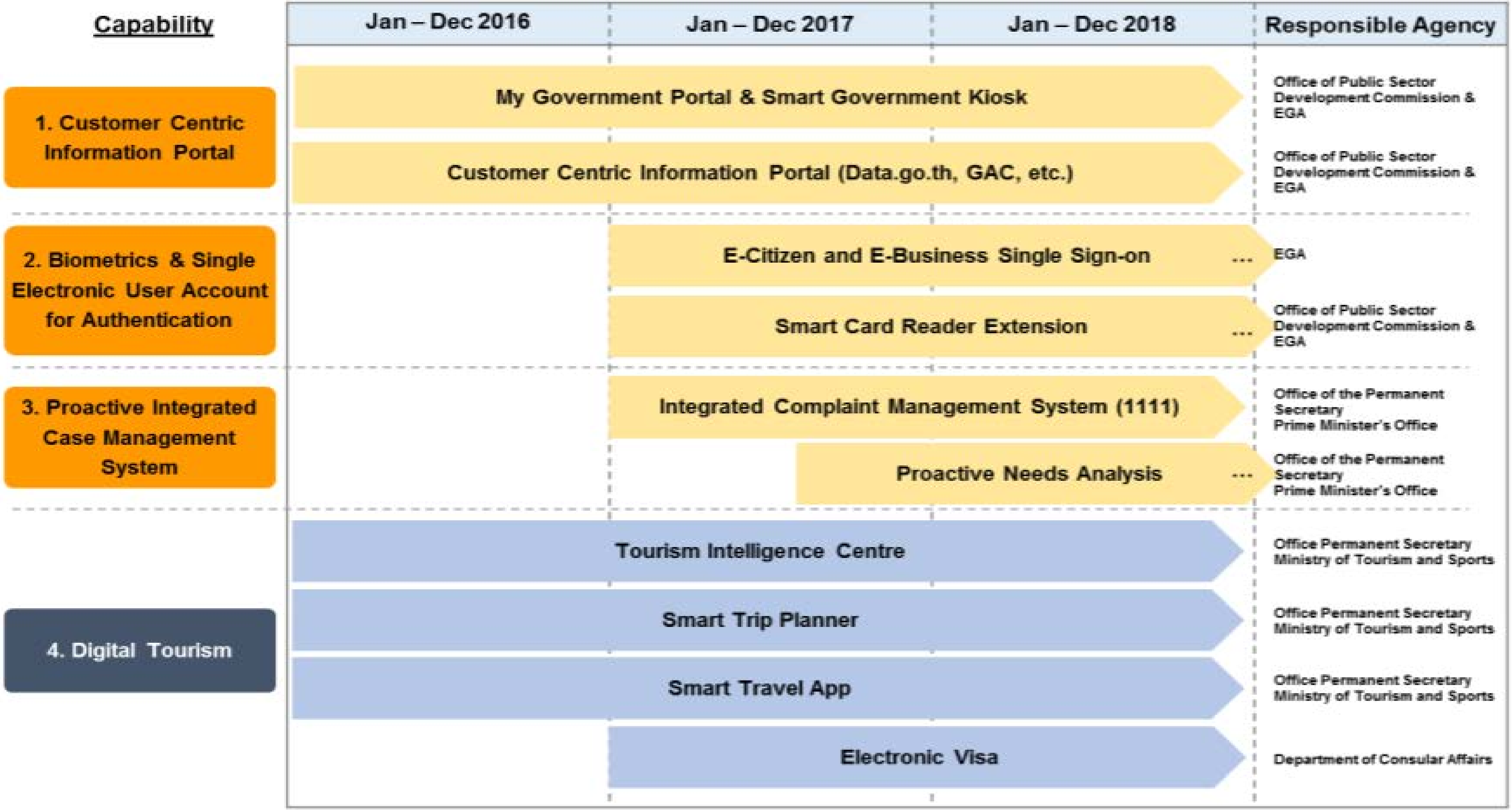
Proposed 3 Year Digital Government Masterplan – 1st Priority





*Cannot begin within 2016 because data integration must be completed beforehand

3 Year Digital Government Masterplan – 2nd Priority



3 Year Digital Government Masterplan – 3rd Priority

Capability	Jan – Dec 2016	Jan – Dec 2017	Jan – Dec 2018	Responsible Agency
1. Trade Single Window (B2B & B2G)			Regulatory Single Window ...	Customs Department
2. Proactive Public Safety			Safe City ...	Royal Thai Police
			Digital Police ...	Royal Thai Police
3. Integrated & Automated Border Management			Advance Passenger Processing ...	Immigration Bureau
			Automated Gate Expansion ...	Immigration Bureau
4. Natural Disaster Management Driven by Scenario-Based Simulations			Natural Disaster Data Integration ...	Department of Disaster Prevention and Mitigation
5. Integrated Crisis Management Practices			Personalized Warning System ...	Department of Disaster Prevention and Mitigation
			Intelligence Centre for Crisis Management ...	Department of Disaster Prevention and Mitigation

REALIZING DIGITAL THAILAND

ROLES OF PUBLIC, PRIVATE, AND CIVIL SECTORS

Private sector and civil society

invest in high-speed networks, introduce innovative products and services at fair and competitive prices. Ensure protection and appropriate use of customer data, and contribute to digital literacy, online safety, innovation, entrepreneurship, and an equitable digital society by undertaking impactful social programming.

Government

Facilitate an environment based on transparent and investment-conducive legal, tax, and regulatory frameworks in order to promote a truly competitive, dynamic, investment-led mobile sector. Digitalize key public services, and strengthen ICT education and digital inclusion.

Regulator

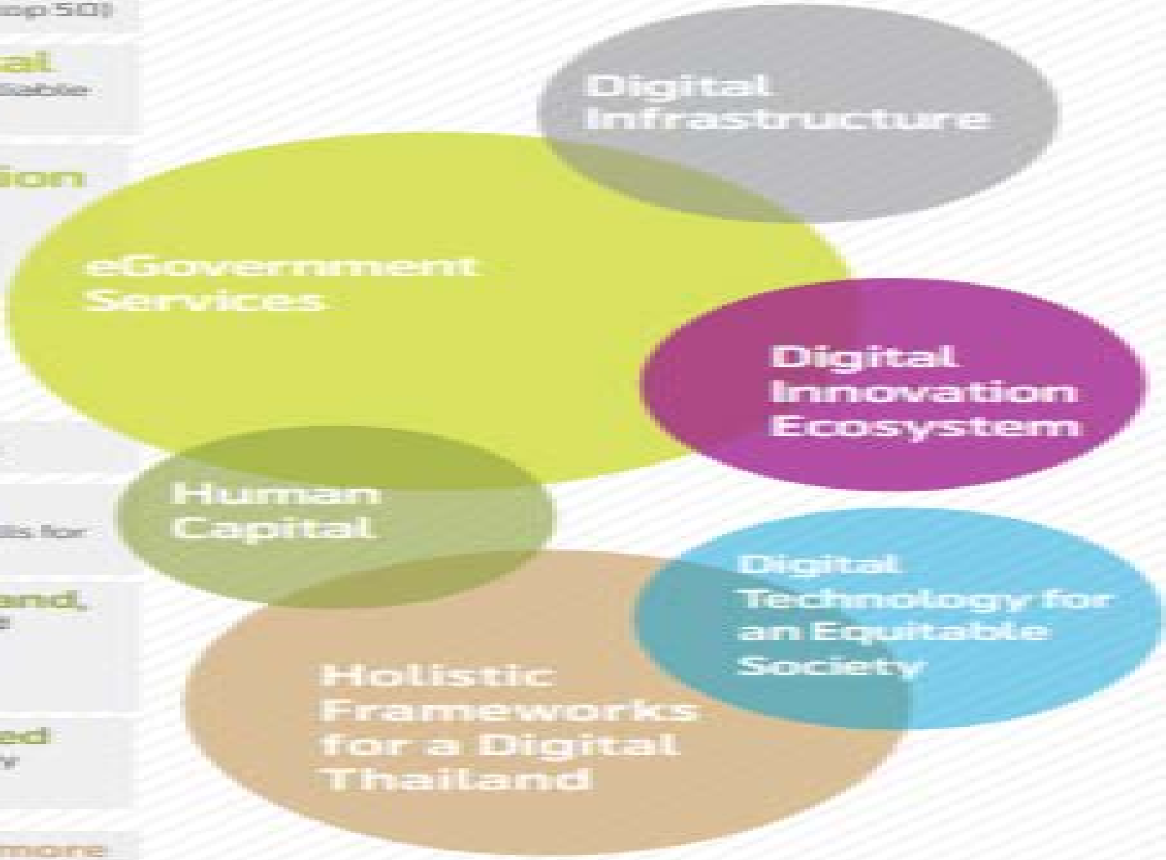
Conduct spectrum auctions to stimulate investment and strengthen coverage and access for consumers. Ensure that consumer rights are safeguarded. Oversee and enforce a level playing field for all operators and service providers, including state-owned enterprises, in order to ensure fair competition. Educate consumers on safe and secure internet usage.

ROADMAP TO 2020

Improve UN eGovernment ranking (currently 102 of 193; target top 50)

Nationwide digital access to stable and reliable public records and services

Public participation in policy decisions through Connected Governance and enhanced connectivity to justice system



133% broadband internet penetration

100% 4G coverage

GDP increase of US $23 billion (THB 730 billion)

100% of Thais connected

Target top quartile of Global Competitiveness Index

Target top quartile of Networked Readiness Index

Thailand in Top 20 in Compass Global Startup Ecosystem ranking

Increased public/private partnership for ecosystem development

50% SME contribution to GDP

100% Thais connected

Nationwide access to digital knowledge and skills for livelihood

Presence of broadband, appropriate technology, and instruction in every public educational facility and information center

Digital skills increased across the workforce in every sector

Regulation allowing more variety of secure electronic formats for e-receipts/e-tax invoices and investments on IT system capacities for Revenue Department

Online Safety education standard for public ICT school curriculum K-12

Digital Economy laws implemented transparently and through public consultation

Ensure future allocation of spectrum through transparent and competitive auction; independent NBTC in place

Enhanced security to citizens and their assets through digital technology

Nationwide access to digital knowledge and skills for livelihood

100% Thais connected

Equivalent quality of connection across the country

Case study

ADVANTECH

Factory Owner Expecting:

Profit = Revenue - Cost

Revenue :

More Orders by Lower MPQ;

Meet Urgent Demand by Shorter lead-time;

→ *Faster Change-over & Enhance production performance*

Cost :

Less Downtime by Higher equipment utility;

Less Labor and Material Waste by Higher yield rate

→ *Immediate stop & Faster shooting production error*

OEE：智慧工廠的監控基礎

Utilize OEE As Manufacturing Guideline of Factory

Schedule	Availability		Performance		Quality		OEE (A x P x Q)
$\frac{20\text{ hrs}}{24\text{ hrs}}$	$\frac{18\text{ hrs}}{20\text{ hrs}}$	x	$\frac{50\text{ pcs}}{60\text{ pcs}}$	x	$\frac{45\text{ pcs}}{50\text{ pcs}}$	=	68%

Location: Taiwan

Customer Pain Points & Critical Task Requirements

Pain Points

- If manufacturing industry wants to transform into a smart factory, equipment networking is the first task.
- Can a traditional manufacturing factory like ours also implement OEE/SRP ?
- There are so many CNC machine tools of different brands, age-old machines and equipment exclusively made by different manufacturers
- Can all their information be transparent and visualized ?

Location: Taiwan

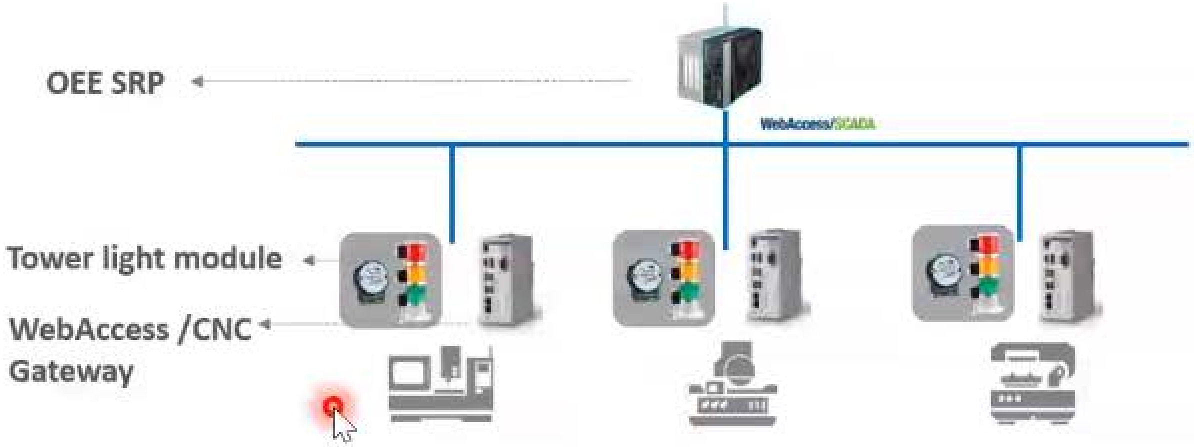
Application Case Study #1

Project Background

- **Adopted Advantech's OEE SRP** to build a real-time production and equipment management platform for optimizing the manufacture of CNC tools, specialized machines, and PLC-based equipment while improving production efficiency
- The factory has more than 20 units of CNC machine tools, as well as many outdated equipment, special machines and PLC-based machines.
- "This factory has only people's productivity, but no machine's utilization."

Location: Taiwan

Advantech Solution Architecture Proposal



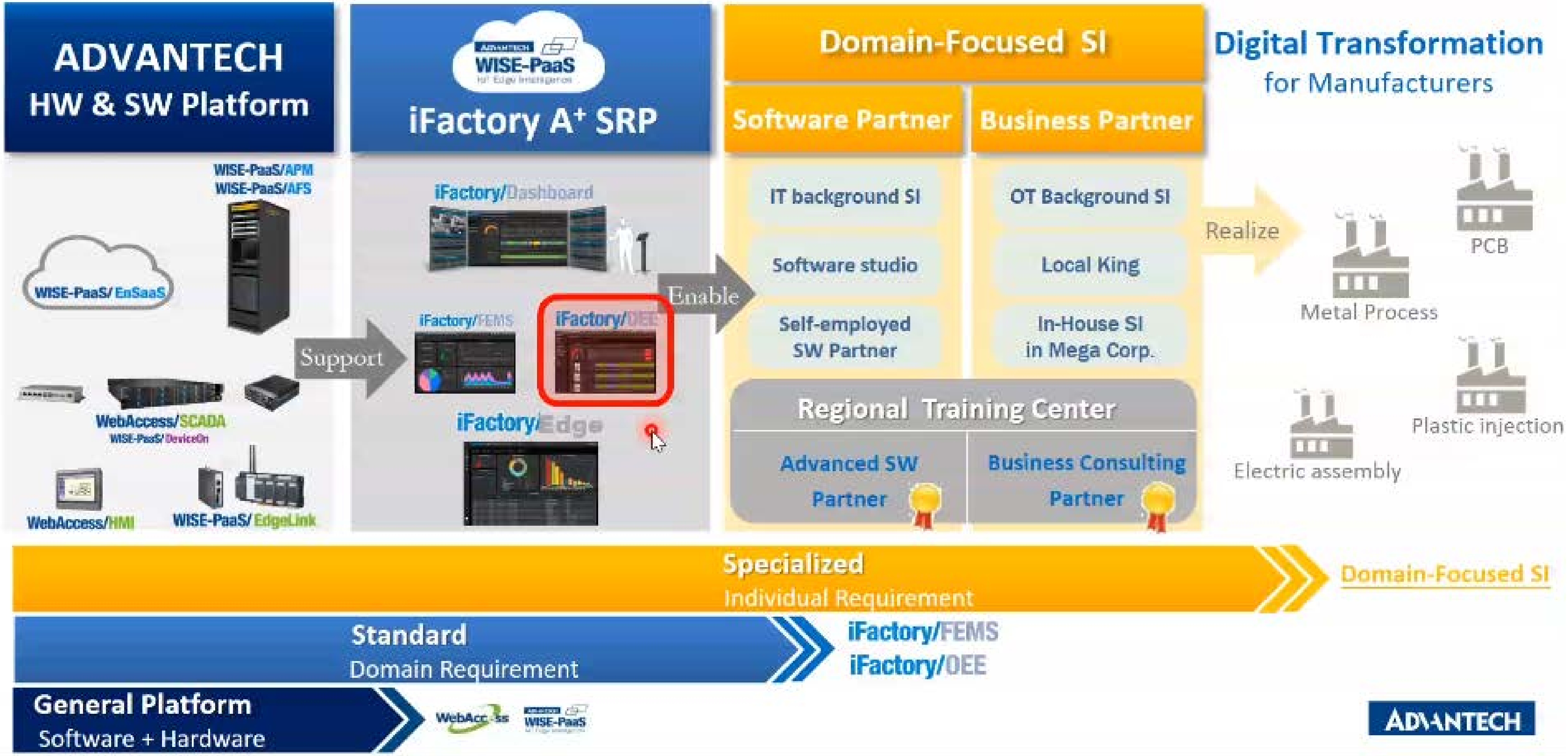
Project Benefit & ROI

- The system is able to collect the **production data** of various machines on the production line,
- **To calculate and compile data to analyze the equipment availability.**
- **Data is graphically presented** on the computer screen in the central control room.
- The managers **get real time information at a glance**
- **Can access historical data** at any time for optimizing decision management to increase production efficiency.
- The ready-made dashboards help to **avoid designing and developing from scratch**

Advanctech’s Technology

Value Chain of iFactory Business

iFactory 生態價值鏈



OEE/SRP – Overall Equipment Efficiency Solution

Instant Monitoring

Tracking & Analysis

Future Prediction

A: Machine Availability

Monitoring : Real-time **machine failure condition**
Tracing: Tracking long-term **shifting efficiency**
Prevention: remark for special SKU for pre-alarming

P: Manufacturing Performance

Monitoring: real time alarm for **production error**
Tracking: tracing **P & Q condition** for special SKU
preventive :pre-alarm for special low P SKU

Q: Product Quality

Monitoring: real time notify by Phone
Tracking: Pareto **chart for Error** frequency
Preventive: focus major resource on critical error

OEE Benefit (A): Digital Twins
Combine Real-time machine condition & Production line behavior

Capacity

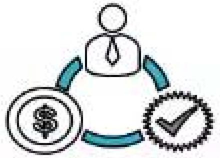
Setup machine's standard **operation status (Run/Error/Wait/Stop/Break)** · and connecting to MES to acquire **change line period** , Visualize all **loss time** in production time.

ADVANTECH

OEE Benefit (B): Production Efficiency Comparison (A & P & Q)

Production

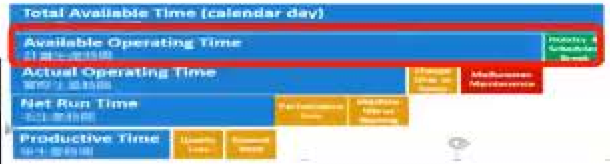
Tracing different **equipment's Availability / Performance / Quality** by separated shift, digging out the problem to enhance the productivity



Improve ROI

OEE Feature (C):
Total Equipment Efficiency Performance (TEEP)

Calculate **machine's full time utilization** to clarify equipment's financial return, and help to evaluate following investment plan.

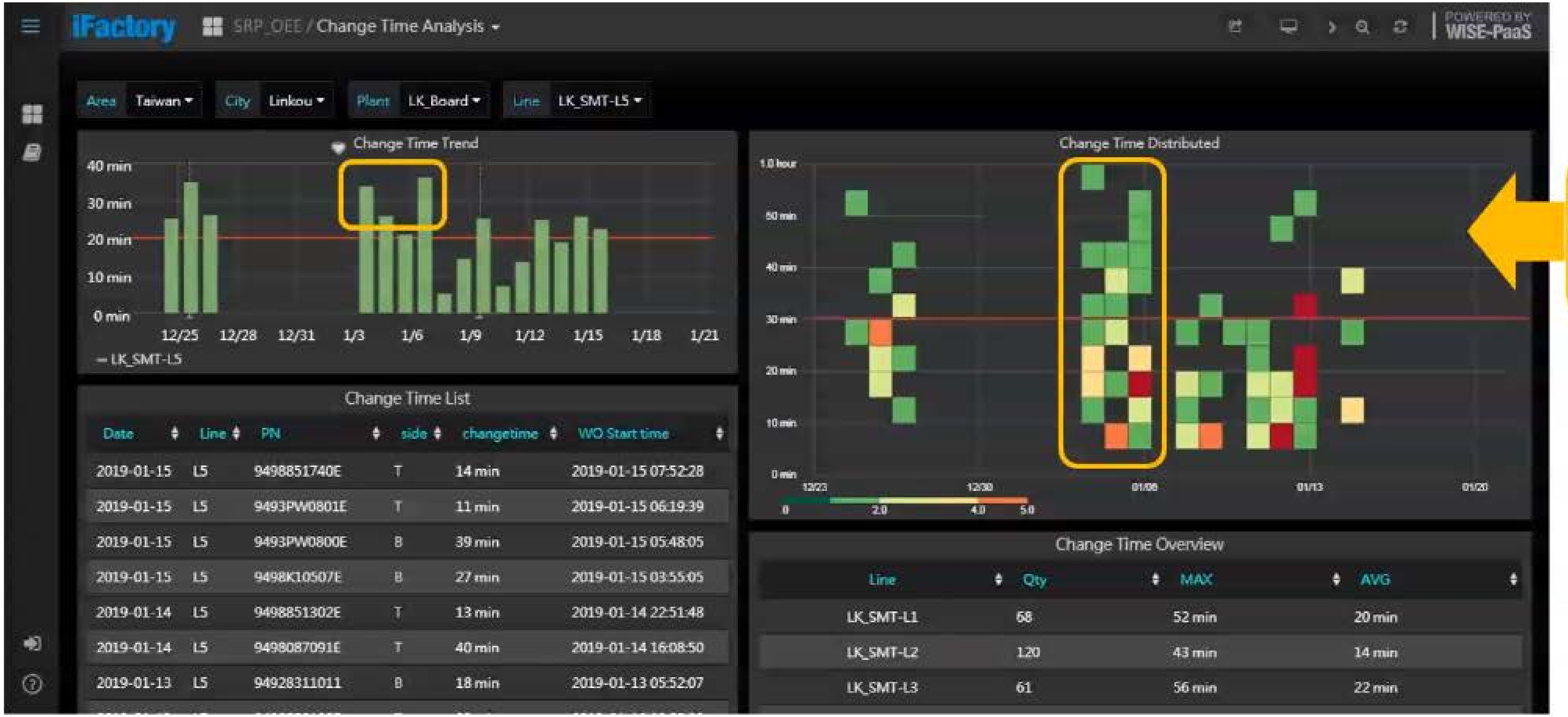


Low TEEP:
Postpone equipment purchase plan

OEE Feature (D) : Chang-over Speed

Efficiency

Demonstrating **average change line time** to see the differentiation day by day.
Heatmap show the detail of change time differentiations, to discover the potential opportunity to twist the loss.



Date	Line	PN	side	changetime	WO Start time
2019-01-15	L5	9498851740E	T	14 min	2019-01-15 07:52:28
2019-01-15	L5	9493PW0801E	T	11 min	2019-01-15 06:19:39
2019-01-15	L5	9493PW0800E	B	39 min	2019-01-15 05:48:05
2019-01-15	L5	9498K10507E	B	27 min	2019-01-15 03:55:05
2019-01-14	L5	9498851302E	T	13 min	2019-01-14 22:51:48
2019-01-14	L5	9498087091E	T	40 min	2019-01-14 16:08:50
2019-01-13	L5	94928311011	B	18 min	2019-01-13 05:52:07

Line	Qty	MAX	AVG
LK_SMT-L1	68	52 min	20 min
LK_SMT-L2	120	43 min	14 min
LK_SMT-L3	61	56 min	22 min

Long Change line event
Operator shall check what happen in that event

ADVANTECH

OEE Benefit (E): Machine Error Condition

Setup **machine error category** base on specialized error definition by each industry,
Operators can monitor and checking error condition & frequency easily

- Total Available Time (calendar day)
- Planned Operating Time | Scheduled Break
- Actual Operating Time | Change | Mal-function
- Net Run Time | Idle | P. Loss
- Productive Time | rework | Q. Loss

Standard Error Code

E01. Equipment mal-function
- E0101 Shaper failure
- E0102 un-define failure

E02. Molding change & adjustment
- E0201 Change molding
- E0202 pre-heating

E03. Un-Loading & Idle
- E0301 Material Shortage
- E0302 Machine cleaning & exam

E04. Down-speed production
- E0401 new labor

E05. Quality Failure & Re-work
- E0501 Yield rate by re-work time
- E0502 Scrapped rate by working time

E06. new product launching loss
- E0601

E07. Scheduled break
- E0701 schedule maintenance
- E0702 resting

Customized Error Code

EX: E010001

Major Classification | Sub Classification | Series number

- E010001 → Repair team 1
- E010102 → Repair team 2
- E010103 → External Repair

MQTT

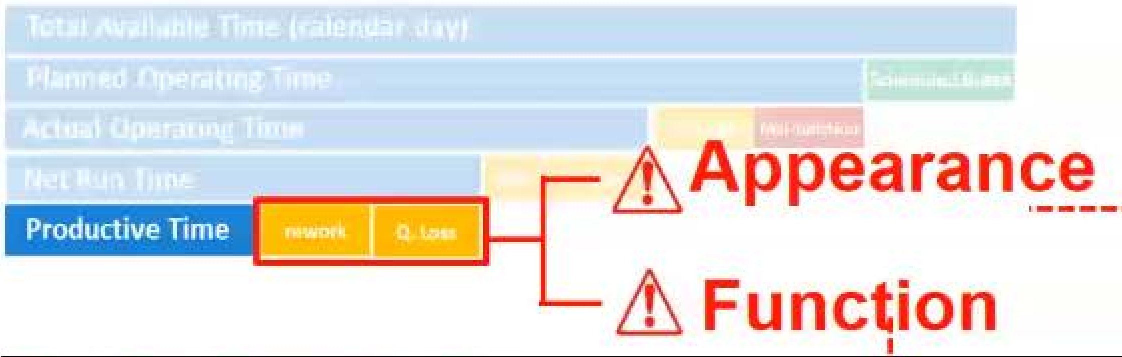
iFactory Rest API

External ERP & MES

ADVANTECH

OEE Benefit (F): Quality Defect

Setup **product quality defect category** base on general production defect definition,
Operators can monitor and checking error condition & frequency easily



Standard Defect Code

QA Appearance Failure
- QA0101 Impurity
- QA0102 Scratch
- QA0103 Uneven Painting
- QA0104 Crushed

QF Function Failure
- QF0101 OS Failure
- QF0102 Screen Failure
- QF0103 IO port Failure
- QF0104 LED light Failure

Customized Defect Code

EX: Q010001

Major Classification | Sub Classification | Series number

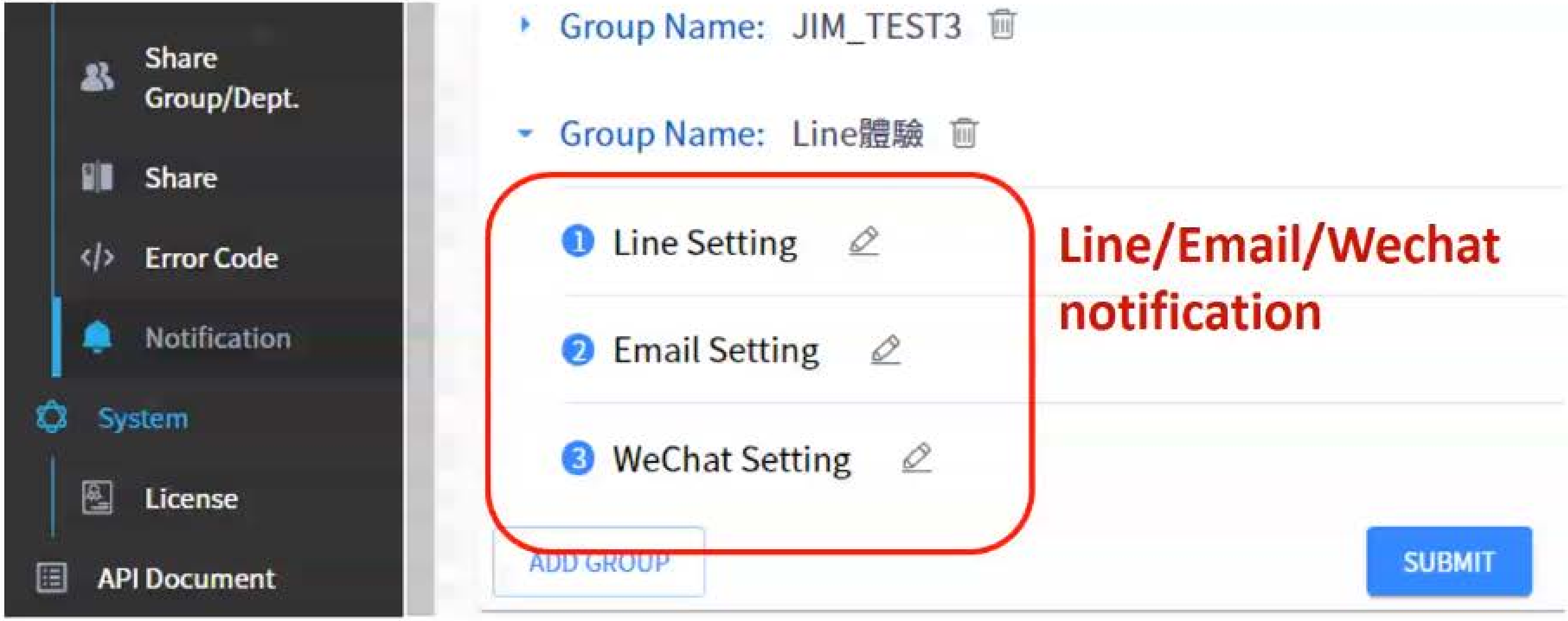
- Q010001 → Repair team 1
- Q010102 → Repair team 2
- Q010103 → External Repair

ADVANTECH

OEE Total Dashboard (OEE其他功能)

iFactory External Notification
智慧工廠解決方案 統整警報介面

Multiple external notification: including **Email & Line & Wechat.**
提供多元警報通報工具：包括Email & Line & 微信。



ADVANTECH

Machine Monitoring Box

iFactory Smart edge/CNC
(P/N:TBD)

Standard data items:
TBD

SIEMENS FANUC
OKUMA HEIDENHAIN
Mazak MITSUBISHI ELECTRIC

iFactory Smart edge/Injection
(P/N:TBD)

Standard data items:
TBD

Sumitomo FANUC
TOYO TECHMATION
LNC MIRLE

iFactory Smart edge/Robot
(P/N:TBD)

Standard data items:
TBD

YASKAWA FANUC
DELTA TOSHIBA
LNC

iFactory Smart edge/Secs Gem
(P/N:TBD)

Standard data items:
TBD

SECS/GEM OPC UA

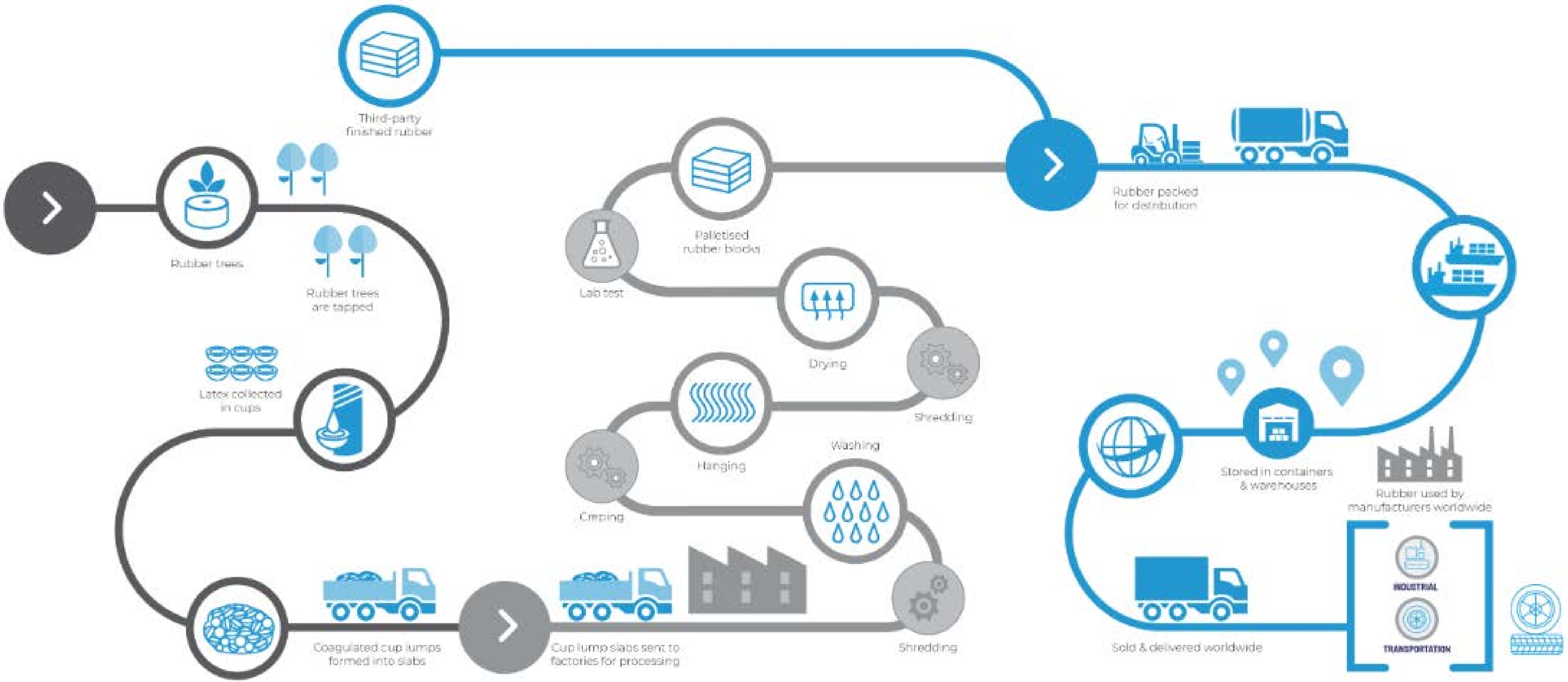
ADVANTECH

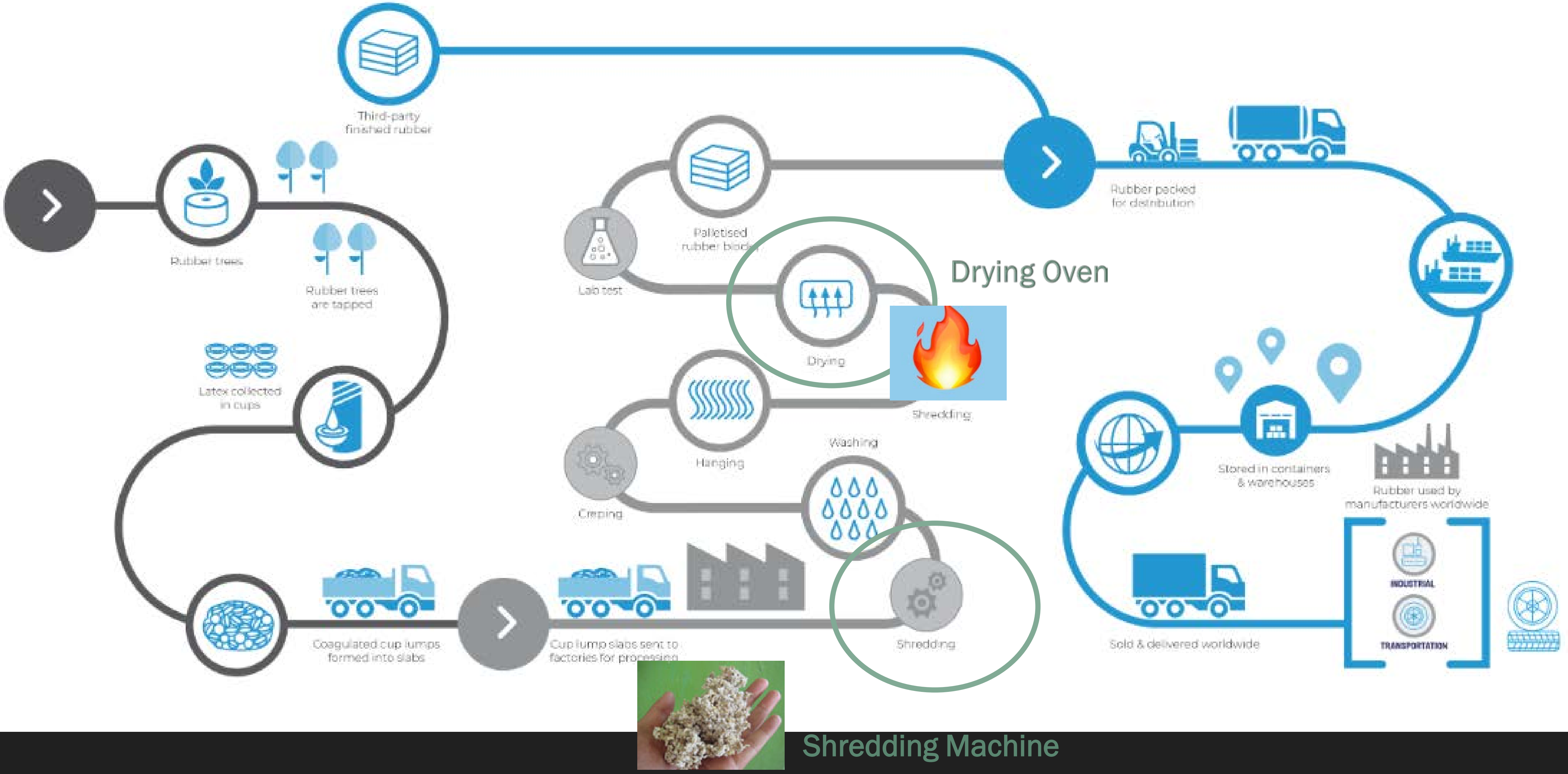
Case Study

HOW TO APPLY AI IN INDUSTRY

Crepe Rubber Production System

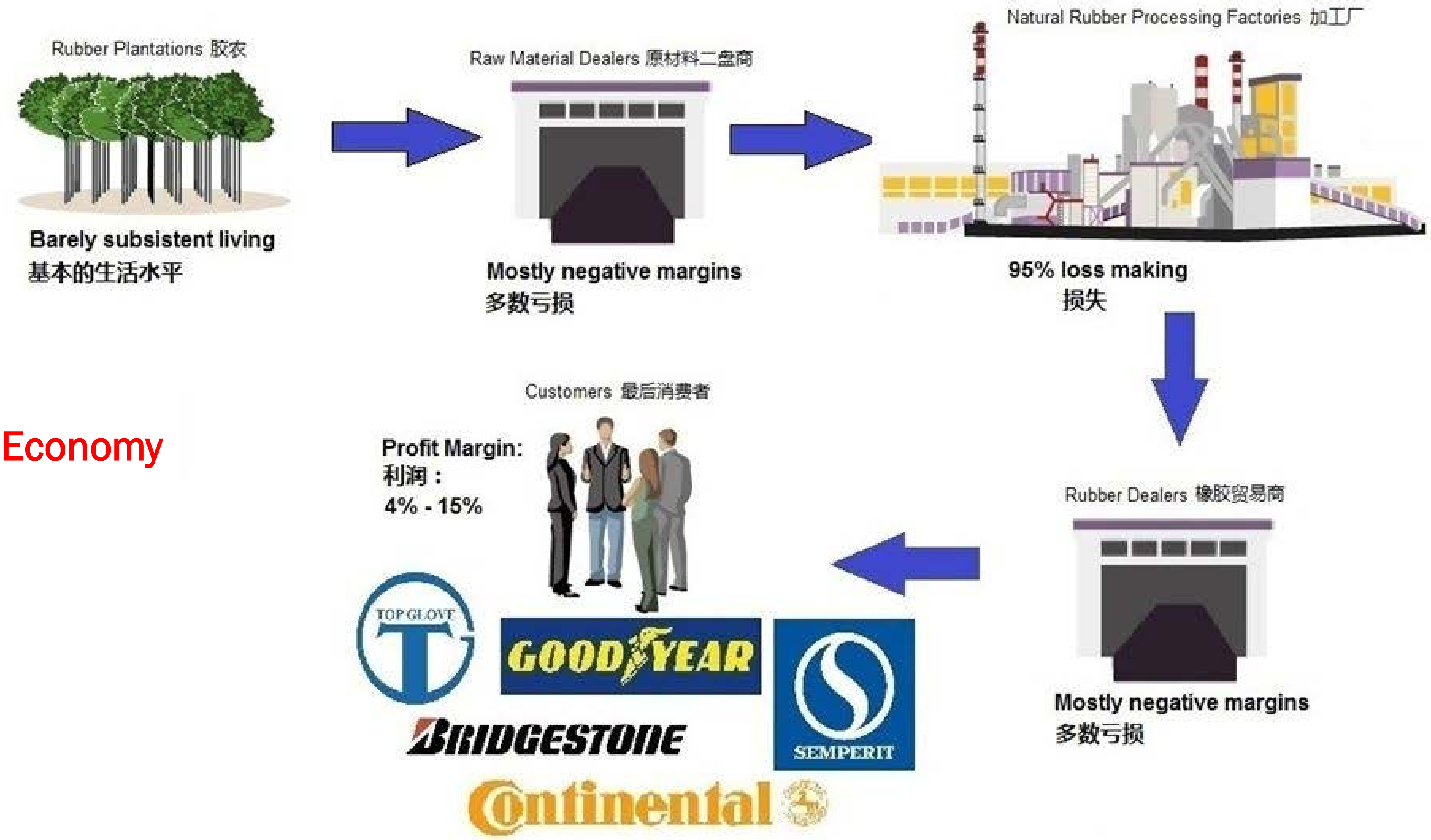
Rubber Tree → Crepe Rubber → STR → Tire


Third-party finished rubber
Rubber trees
Rubber trees are tapped
Latex collected in cups
Coagulated cup lumps formed into slabs
Cup lump slabs sent to factories for processing
Shredding
Washing
Creping
Hanging
Shredding
Drying
Lab test
Palletised rubber blocks
Rubber packed for distribution
Stored in containers & warehouses
Rubber used by manufacturers worldwide
Sold & delivered worldwide
INDUSTRIAL
TRANSPORTATION

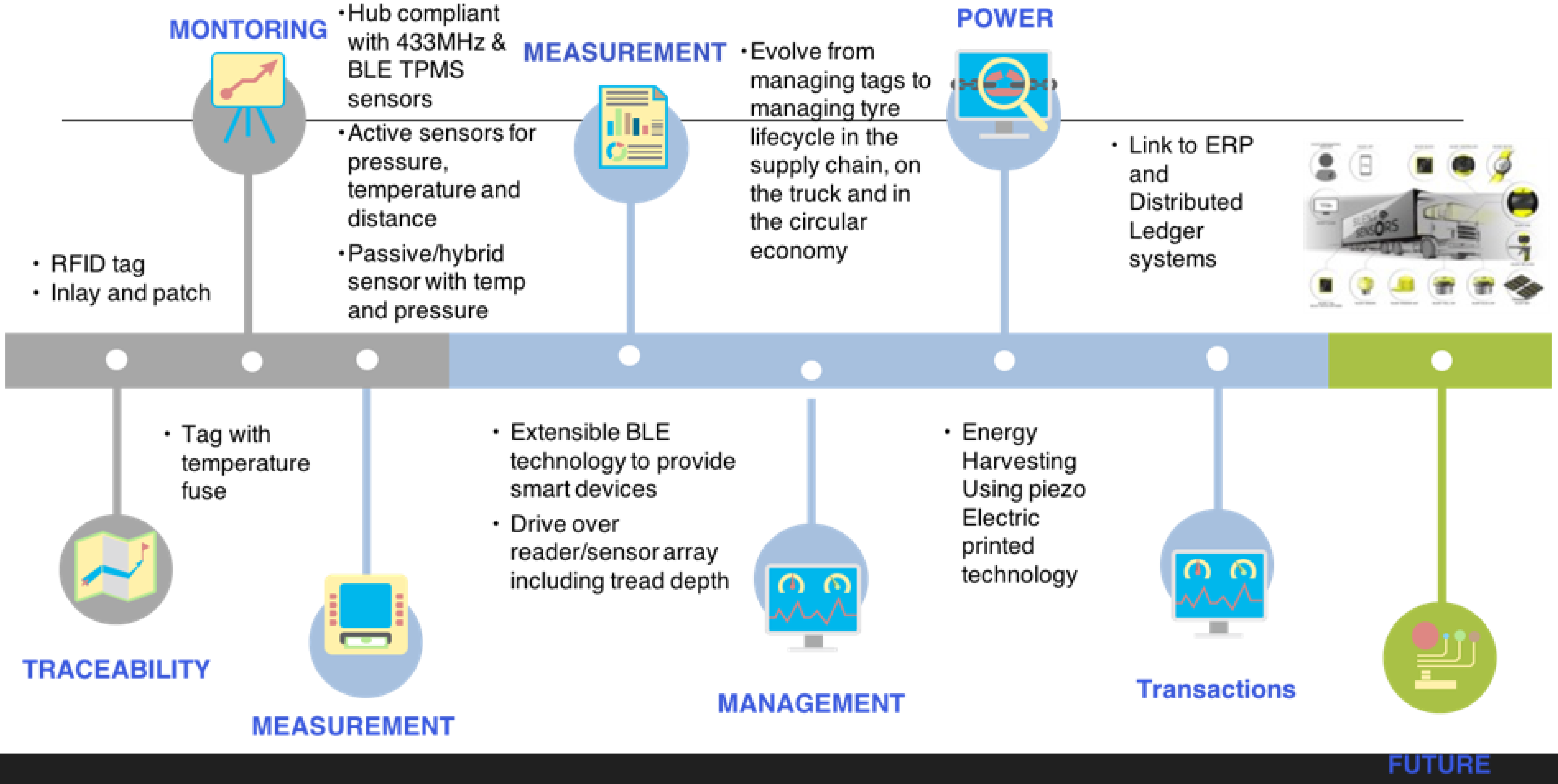

Third-party
finished rubber
Rubber trees
Rubber trees
are tapped
Latex collected
in cups
Coagulated cup lumps
formed into slabs
Cup lump slabs sent to
factories for pro
Lab test
Palletised
rubber bloc
Drying
Drying Oven
Shredding
Hanging
Washing
Creping
Shredding
Rubber packed
for distribution
Stored in containers
& warehouses
Rubber used by
manufacturers worldwide
INDUSTRIAL
TRANSPORTATION
Sold & delivered worldwide
Shredding Machine

Rubber Value Chain

International Rubber Association



Circular Economy


TRACEABILITY
• RFID tag
• Inlay and patch
MONTORING
• Tag with temperature fuse
• Hub compliant with 433MHz & BLE TPMS sensors
• Active sensors for pressure, temperature and distance
• Passive/hybrid sensor with temp and pressure
MEASUREMENT
MEASUREMENT
• Extensible BLE technology to provide smart devices
• Drive over reader/sensor array including tread depth
• Evolve from managing tags to managing tyre lifecycle in the supply chain, on the truck and in the circular economy
MANAGEMENT
POWER
• Energy Harvesting Using piezo Electric printed technology
• Link to ERP and Distributed Ledger systems
Transactions
FUTURE

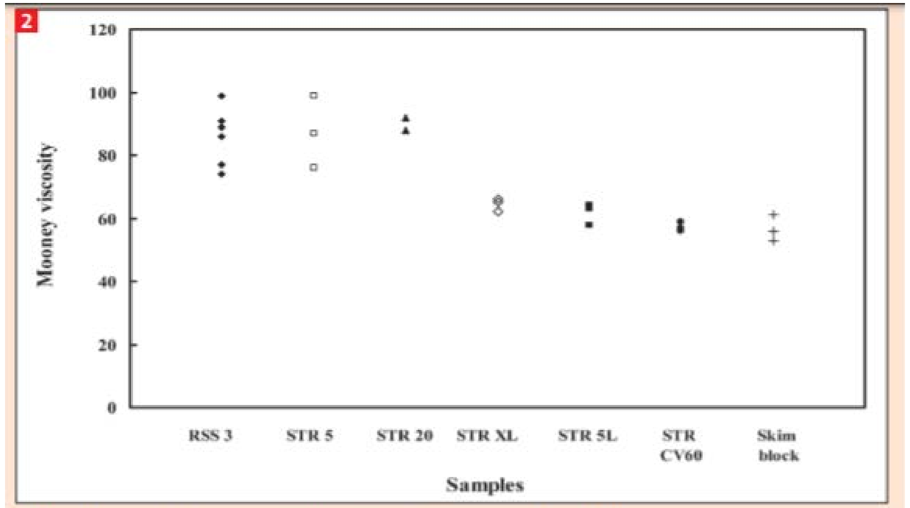
STANDARD THAI RUBBER SPECIFICATION

Parameter	STR10	STR10 CV	STR20	STR20 CV	STR GP	USS 10	Test Method
Dirt (max, % wt)	0.08	0.08	0.16	0.16	0.10	0.05	ISO 249
Ash (max, % wt)	0.60	0.60	0.80	0.80	0.75	0.50	ISO 247
Volatile Matter (max , % wt)	0.80	0.80	0.80	0.80	0.80	0.50	ISO 248
Nitrogen (max , % wt)	0.60	0.60	0.60	0.60	0.60	0.50	ISO 1656
Initial Plasticity (Po) (Min)	30	-	30	-	30	30	ISO 2007
Plasticity Retention Index (Min)	50	50	40	40	60	75	ISO 2930
Mooney Viscosity ML (1+4) 100C	-	60(+7,-5)	-	65(+7-5)	55-65	70-85	ISO 289
Colour Coding Marker	Brown	White on Brown Background	Red	White on Red Background	Yellow	Yellow	

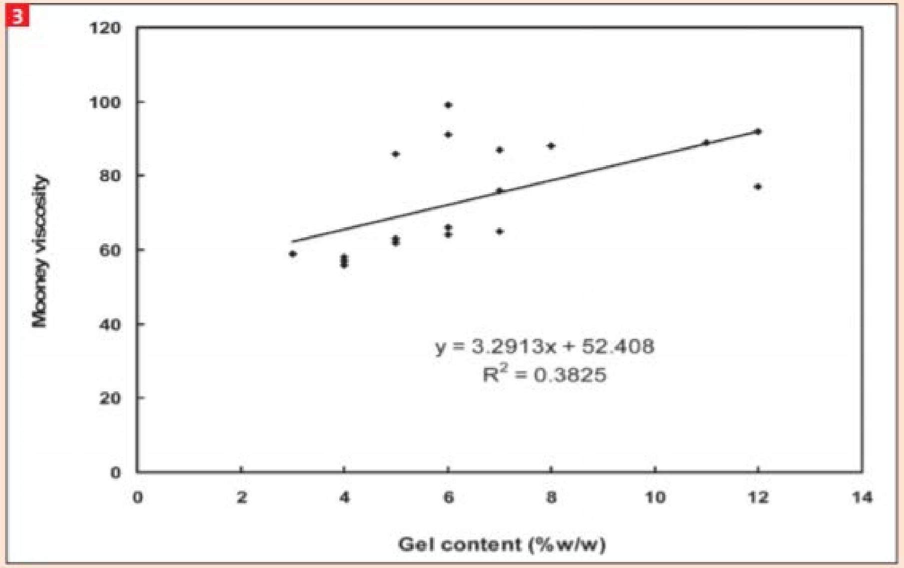
MV and Po

Determination of mooney viscosity and mooney relaxation (MR_{30})

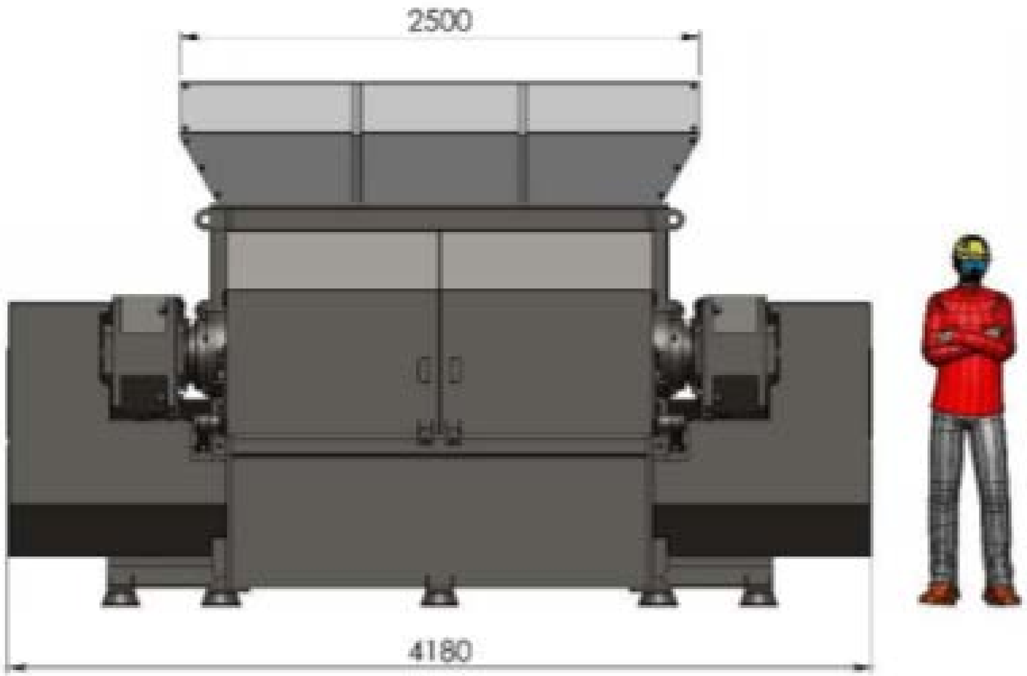
The Mooney viscosity was determined on a viscometer (TECHPRO) by dividing about 25 g into two equal portions. The temperature of test was 100 °C ± 1 °C and large rotor size was used to measure a shear viscosity at strain rate of about 2 sec^{-1}. A rubber sample was pre-heated at 100 °C for 1 min, followed by continuous shear for 4 min. Subsequently, the decay of torque was measured when the rotor was stopped. The percentage of residual torque after rotor stop for 30 sec defines as MR_{30}.



2 Variations in Mooney viscosity among different grades of NR.



3 Correlation between Mooney viscosity and gel content.



Main features

Power installed on the rotor:	55 + 55 kW
Power of the hydraulic control unit:	7,5 kW
Drive:	by belts (no. 2 hydraulic joints on the motor shaft)
Number of rotors:	1
Rotor diameter	480 mm
Rotor length:	2000 mm
Number of reversible tools:	95
N° of usable tools sides:	4
Average number of rotor revolutions per min	80
Weight:	12000 kg
Production :	3,5 - 5 t/h
Safety devices:	emergency stop, drawer reversal system
Manufactured according to EC standards	

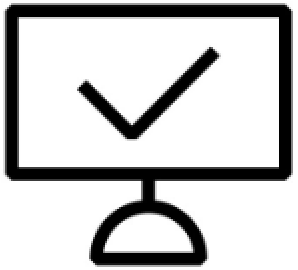
300 KW AC Motor

Monitor

Switchgear conditions such as temperature, current levels, energy consumption, alarm and warning levels are collected and stored for further analysis, real-time data enable user to make right decision at right time.

Analyze

Algorithms that consider multiple data and do not require human input make decisions i.e. whether a temperature increase is a critical situation due to loose connection or a normal situation due to increase load demand.



Predict

Counting repeating activities of a period such as removing and inserting withdrawable functional units in a switchgear assembly decide on the next maintenance cycle. Preventive maintenance based on a schedule is a past.

Optimize

Unusual levels of energy consumption even of smaller loads influence total plant operational costs. Identifying such and similar situations enable process optimization at a new scale.

Condition Monitoring for electrical systems (CMES)

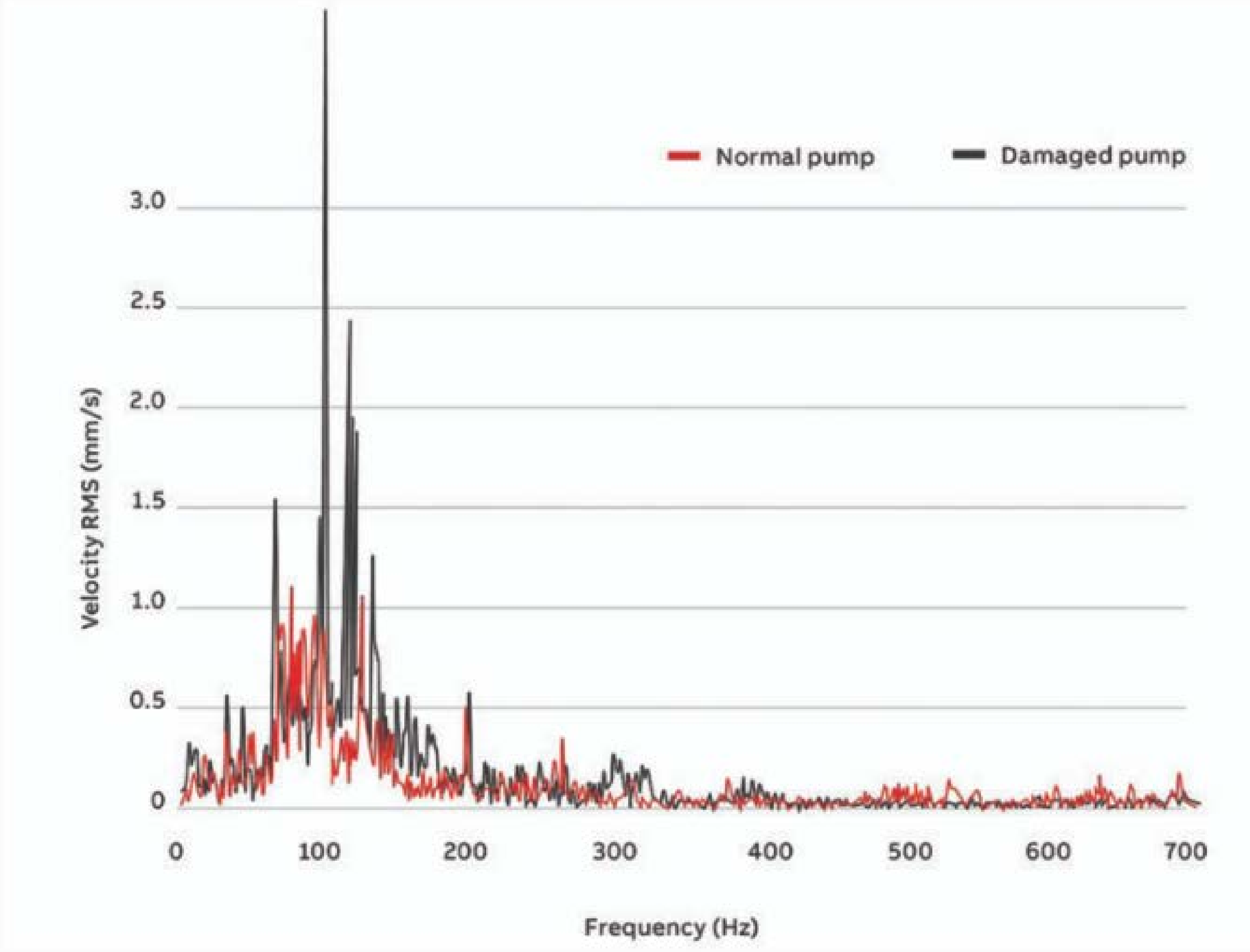
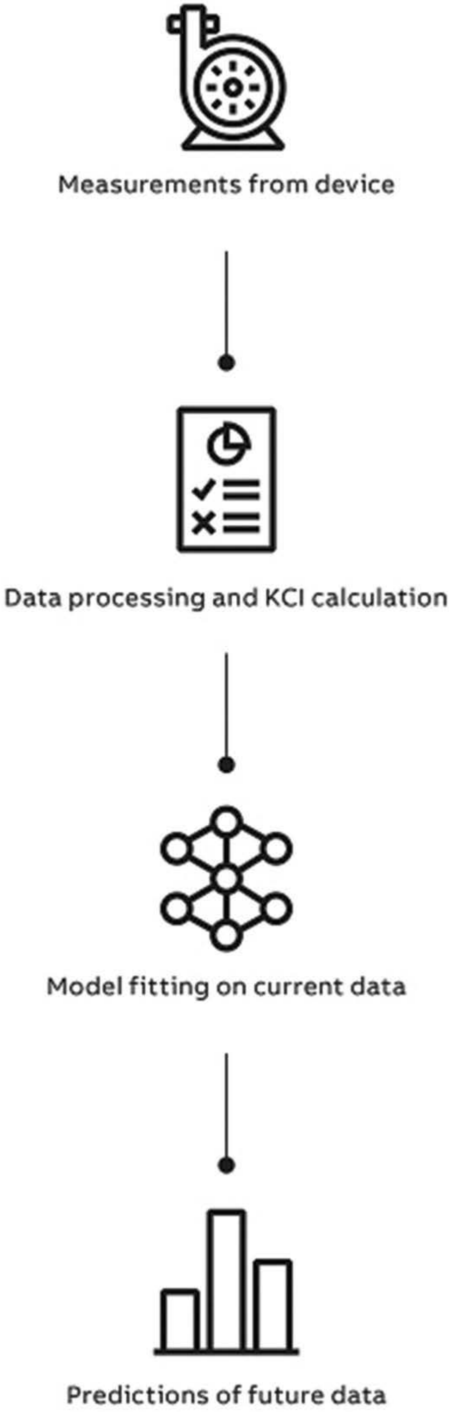


Fig. 3: Example frequency spectrum of a normal pump and a damaged pump.

by Ralf Gitzel, Benedikt Schmidt, Arzam Kotriwala, Ido Amihai, Guruprasad Sosale, James Ottewill; Marco Heese ; Diego Pareschi, ABB

- *Blade problems:* When monitoring pumps, certain peaks in the frequency spectrum indicate damage to the blades in the pump. The blade problem KCI reflects how pronounced these critical peaks are.
- *Flow turbulences:* This KCI indicates irregularities in the flow of liquid passing a pump. Turbulences can be problems in themselves or indicators thereof.
- *Looseness:* The central shaft in rotating equipment is often constrained by the bearings so that its rotational axis does not fluctuate. Excessive clearance, typically caused by wear in the bearing, will mean the shaft will exhibit vertical and horizontal movement which can quickly lead to further damage. The looseness KCI indicates whether and to what degree the equipment suffers from this problem.
- *Misalignment:* All components of rotating equipment must be well aligned. However, damage during transportation or irregularities during operation can cause deviations from the ideal alignment position. Like looseness, misalignment can cause further damage to the asset as well as reduce its performance.
- *Imbalance:* Ideally, the rotating elements in a piece of equipment are balanced. This means that the mass is distributed equally in all directions. An example of imbalance would be a piece of matter sticking to one of the blades in a pump, which will exert additional force on the bearings.
- *Cavitation:* Cavitation is a well-known pump related problem. Small, low-pressure bubbles can occur when force is exerted on a liquid in such a way that there are rapid pressure changes. Due to the higher pressure around them, these bubbles can implode and cause damage to the pump. The cavitation KCI detects the occurrence of cavitation-related implosions.



What currents tell us about vibrations

by James Ottewill, ABB Poland

Valuable condition monitoring data, relevant for an entire drive-train, can be unlocked using electrical signals in motors. Advances in sensing, connectivity, cloud and computing technologies are driving the digitisation of industry at an ever-increasing rate. Add analytics algorithms to the mix and customers can extract considerable additional value from their devices, systems and plants. Digitisation […]

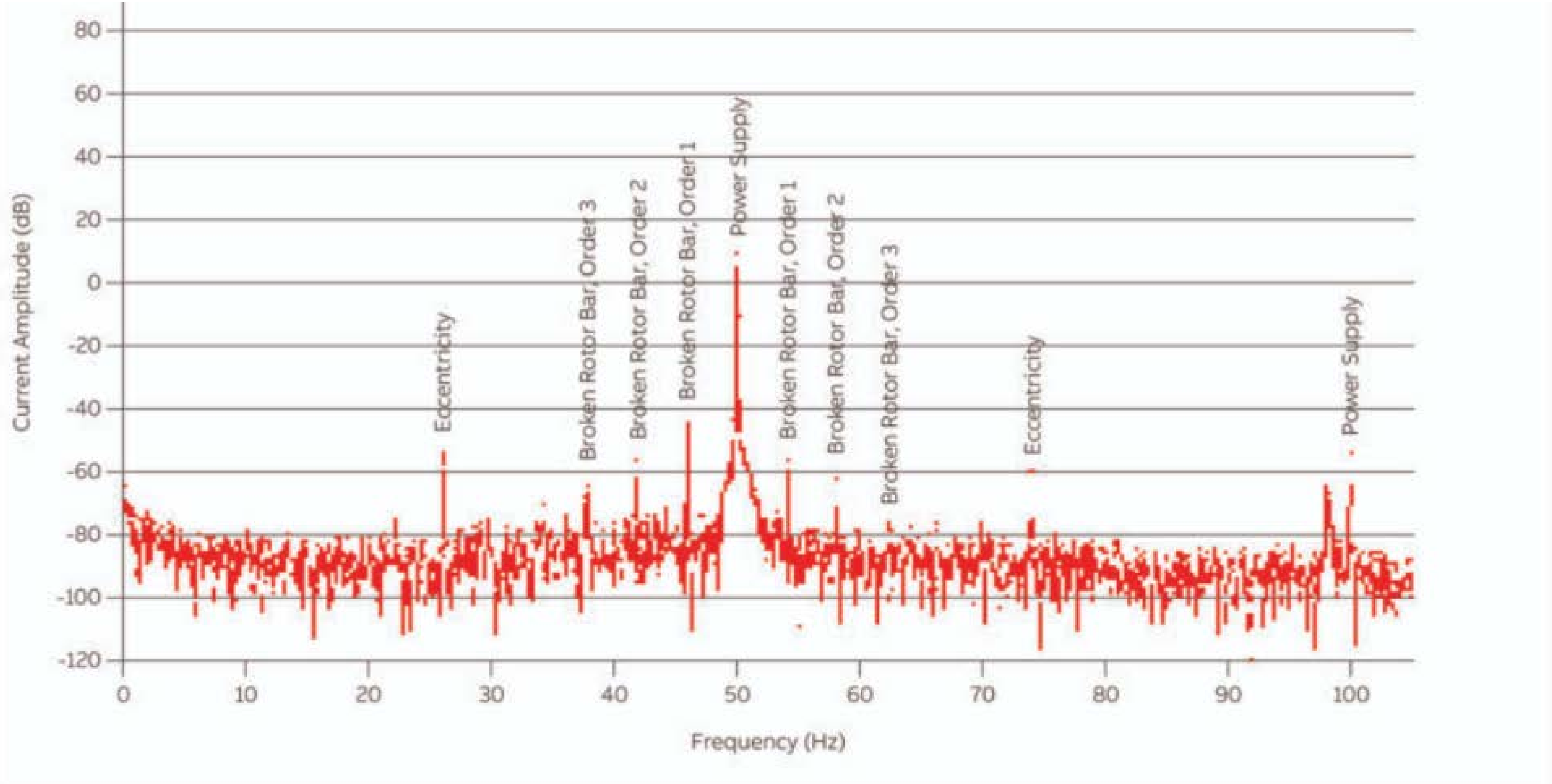


Fig. 1: Current frequency spectrum measured on an experimental induction motor with various seeded faults. Frequency components of interest are highlighted, including those that can be used to diagnose specific fault modes.

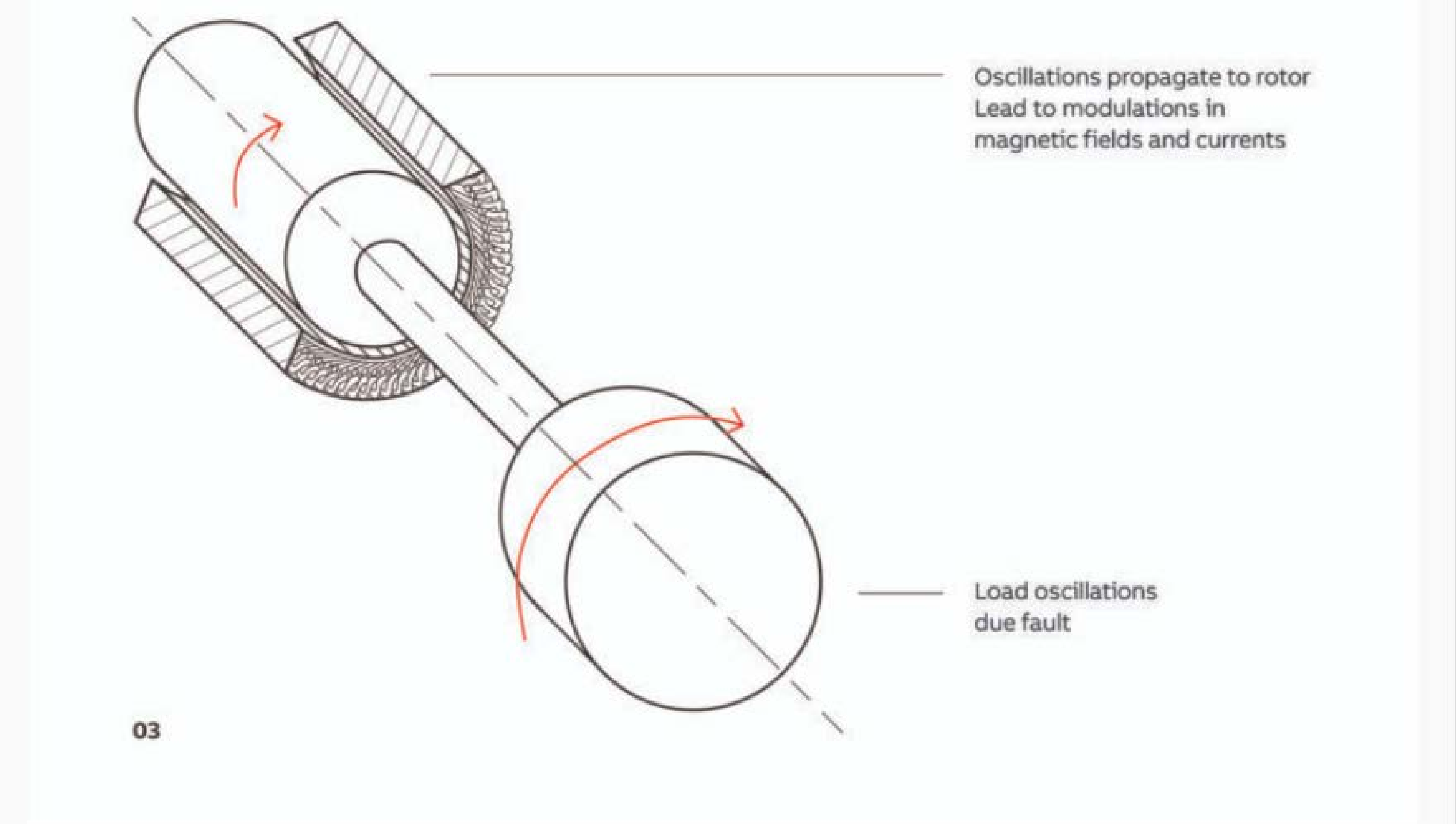


Fig. 2: Oscillations caused by faults in rotating equipment can propagate through to a connected motor.

DIGITAL EDUCATION INSTITUTE

AI analysis

Anomaly Detection

Fault detection

- Use for predictive maintenance where the machine's health data is used to determine if the machine is operating in the normal or abnormal condition.
- anomaly detection or outlier detection in machine learning.
- Application: banking for anomaly detection, video and image analytics, network security and intrusion detection.

Reference: Amruthnath N, Gupta T (2019)

AI/ML Tools for Predictive Maintenance

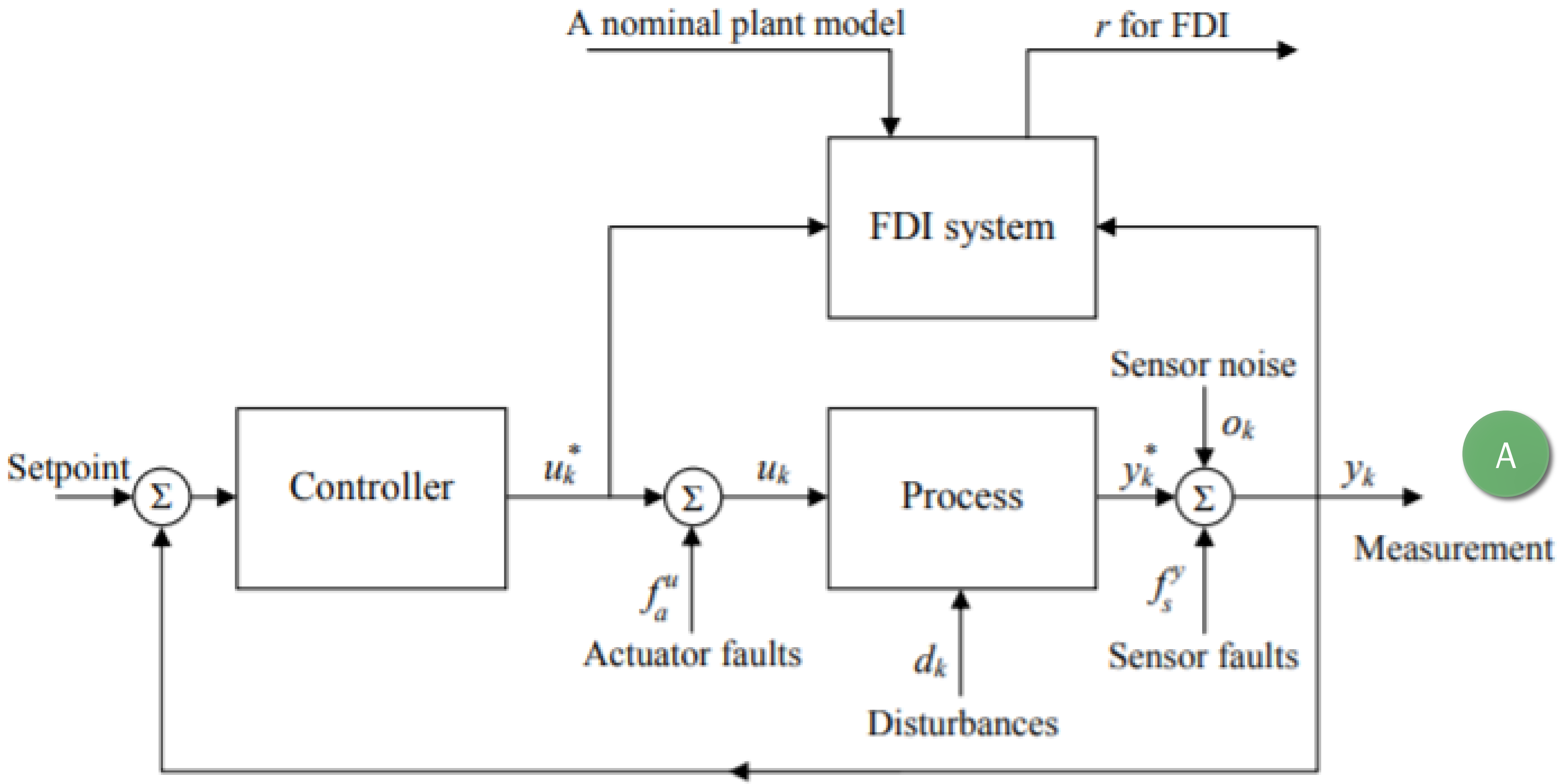
Fault Detection

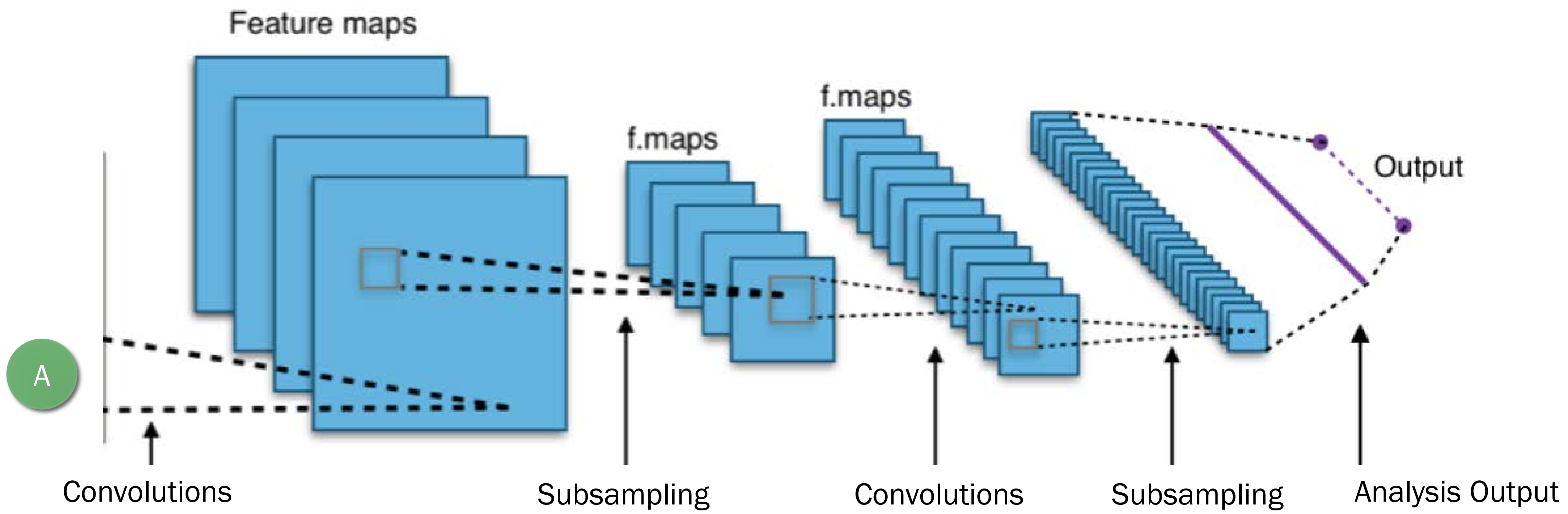
Auto Encoder

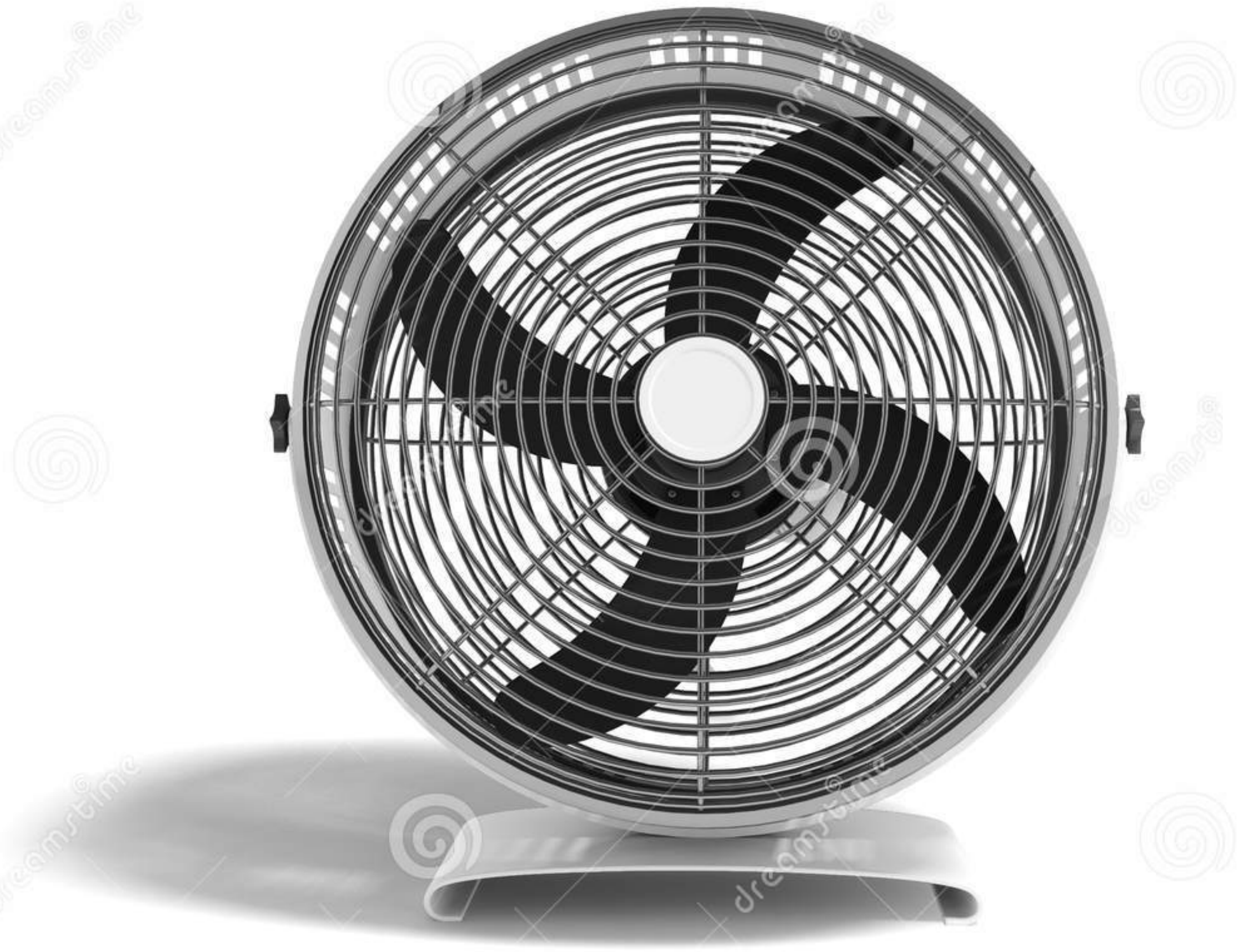
Isolation Forest

One-class SVM

Fault Detection + Isolation (FDI)




Feature maps
f.maps
f.maps
Output
A
Convolutions
Subsampling
Convolutions
Subsampling
Analysis Output



Four different states of the machine were collected

1. Nothing attached to drill press
2. Wooden base attached to drill press
3. Imbalance created by adding weight to one end of wooden base
4. Imbalacne created by adding weight to two ends of wooden base.

- base.csv
- dry run.csv
- imbalance 1.csv
- imbalance 2.csv

From a research study: Amruthnath, Nagdev, and Tarun Gupta., 2018

Raw Data

Base run

time	ax	ay	az	aT
0.004	-0.5076	-0.2454	-0.249	0.616
0.006	-0.1173	0.2752	1.3013	1.335
0.008	0.0114	-0.6306	0.346	0.719
0.019	-0.4323	-0.7868	-0.3854	0.977
0.034	-0.6198	-0.4897	0.03	0.79
0.035	-0.5081	0.1925	-0.2141	0.584
0.053	0.5671	1.0772	-0.0153	1.217
0.071	-0.1315	-0.307	-0.0057	0.334
0.071	-0.1287	-0.4138	0.7425	0.86
0.072	-0.1306	-0.1256	0.1763	0.253
0.087	0.0803	0.6522	-0.4665	0.806
0.107	0.6027	0.7466	0.0124	0.96

Dry Run

time	ax	ay	az	aT
0.002	-0.3246	0.2748	0.1502	0.451
0.009	0.602	-0.19	-0.3227	0.709
0.019	0.9787	0.3258	0.0124	1.032
0.027	0.6141	-0.4179	0.0471	0.744
0.038	-0.3218	-0.6389	-0.4259	0.833
0.047	-0.3607	0.1332	-0.1291	0.406
0.064	0.5815	0.5988	0.5352	0.992
0.075	0.3712	-0.3249	-1.1551	1.256
0.101	-0.2175	-1.1527	-0.8715	1.461
0.102	-0.4639	-0.8331	-1.5144	1.79
0.102	0.5395	0.467	2.7507	2.842
0.11	0.0996	0.9725	0.3242	1.03

Imbalance 1

time	ax	ay	az	aT
0.01	0.0201	1.107	0.5514	1.237
0.01	1.8176	2.2123	-1.2754	3.134
0.011	0.6783	0.1174	1.1079	1.304
0.026	-0.5725	-0.7905	-0.4293	1.066
0.031	0.0426	-1.2621	-2.2765	2.603
0.04	0.4798	-1.3208	1.2993	1.914
0.051	-0.9578	0.0218	-0.8101	1.255
0.06	-0.6575	0.396	0.5738	0.958
0.072	0.2512	0.4187	0.7725	0.914
0.08	0.5931	-0.3708	0.2409	0.74
0.091	0.3196	1.1095	-0.1578	1.165
0.101	0.6096	1.2439	0.6694	1.538

Imbalance 2

time	ax	ay	az	aT
0.009	1.5809	-0.6104	3.7975	4.158
0.01	-0.8242	-1.3934	0.1212	1.623
0.02	-1.2101	0.2236	-1.3094	1.797
0.03	-0.9388	-0.2382	-1.0066	1.397
0.04	0.7131	0.5219	0.8046	1.195
0.056	0.7369	0.7009	1.5935	1.89
0.057	-0.0817	0.8219	0.7232	1.098
0.077	-0.1853	-0.5767	-2.9806	3.042
0.078	-1.5026	-1.8856	-1.2389	2.711
0.093	-1.1614	-2.3352	0.6657	2.692
0.095	0.3131	2.3172	0.8872	2.501
0.109	0.1816	2.2926	-1.7368	2.882

ax is the acceleration on x axis
ay is the acceleration on y axis,
az is the acceleration on z axis,
at is the G's.

FAULT DETECTION

In [2]:
```r
options(warn=-1)

# load libraries
library(mdatools) #mdatools version 0.9.1
library(caret)
library(foreach)
library(dplyr)
library(mclust)
```

In [3]:
```r
#setwd("/Experiment")
#read csv files
file1 = read.csv("dry run.csv", sep=",", header =T)
file2 = read.csv("base.csv", sep=",", header =T)
file3 = read.csv("imbalance 1.csv", sep=",", header =T)
file4 = read.csv("imbalance 2.csv", sep=",", header =T)
head(file1)
```

time	ax	ay	az
0.002	-0.3246	0.2748	0.1502
0.009	0.6020	-0.1900	-0.3227
0.019	0.9787	0.3258	0.0124
0.027	0.6141	-0.4179	0.0471
0.038	-0.3218	-0.6389	-0.4259
0.047	-0.3607	0.1332	-0.1291

In [4]:
```r
# summary of each file
summary(file1)
```

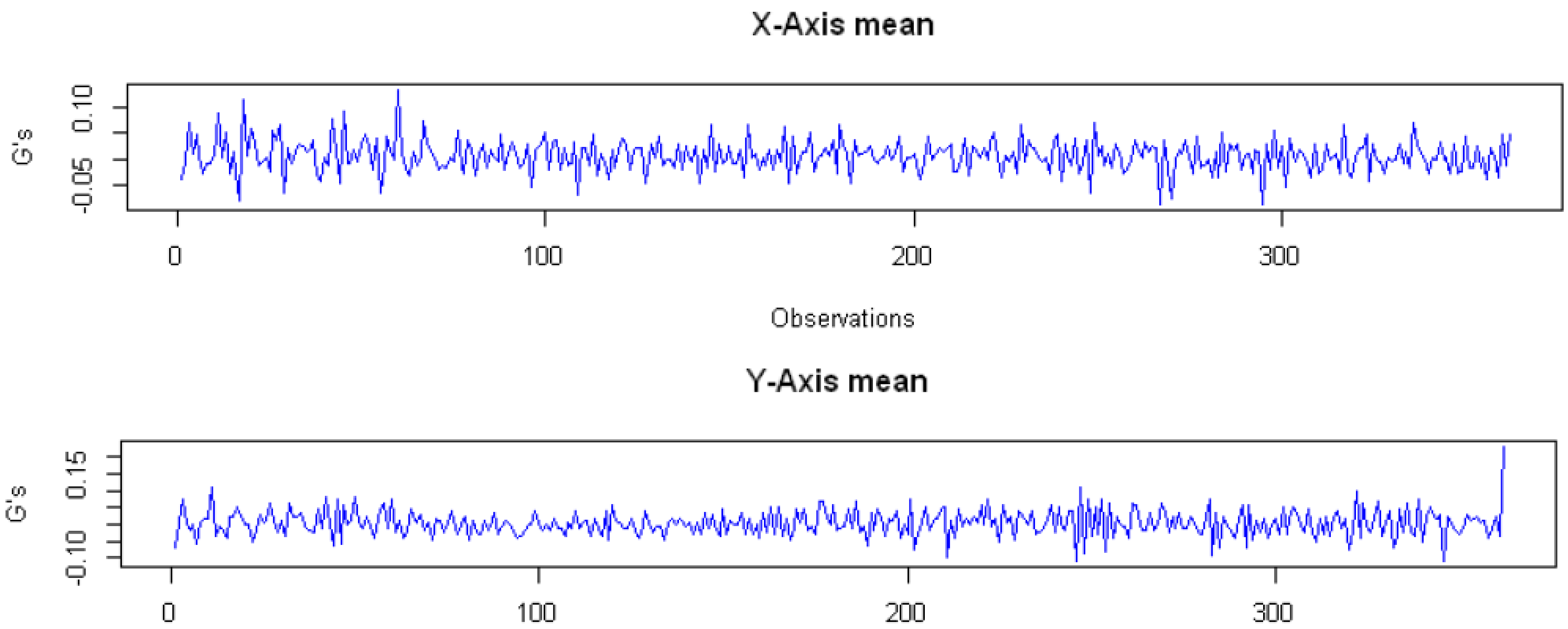
```
      time              ax                  ay                   az
 Min.   : 0.002   Min.   :-2.11880   Min.   :-2.143600   Min.   :-4.1744
 1st Qu.:16.507   1st Qu.:-0.41478   1st Qu.:-0.625250   1st Qu.:-0.7359
 Median :33.044   Median : 0.02960   Median :-0.022050   Median :-0.1468
 Mean   :33.037   Mean   : 0.01233   Mean   : 0.008697   Mean   :-0.1021
 3rd Qu.:49.535   3rd Qu.: 0.46003   3rd Qu.: 0.641700   3rd Qu.: 0.4298
 Max.   :66.033   Max.   : 2.09620   Max.   : 2.003000   Max.   : 4.9466
       aT
 Min.   :0.032
 1st Qu.:0.848
 Median :1.169
 Mean   :1.277
 3rd Qu.:1.579
 Max.   :5.013
```

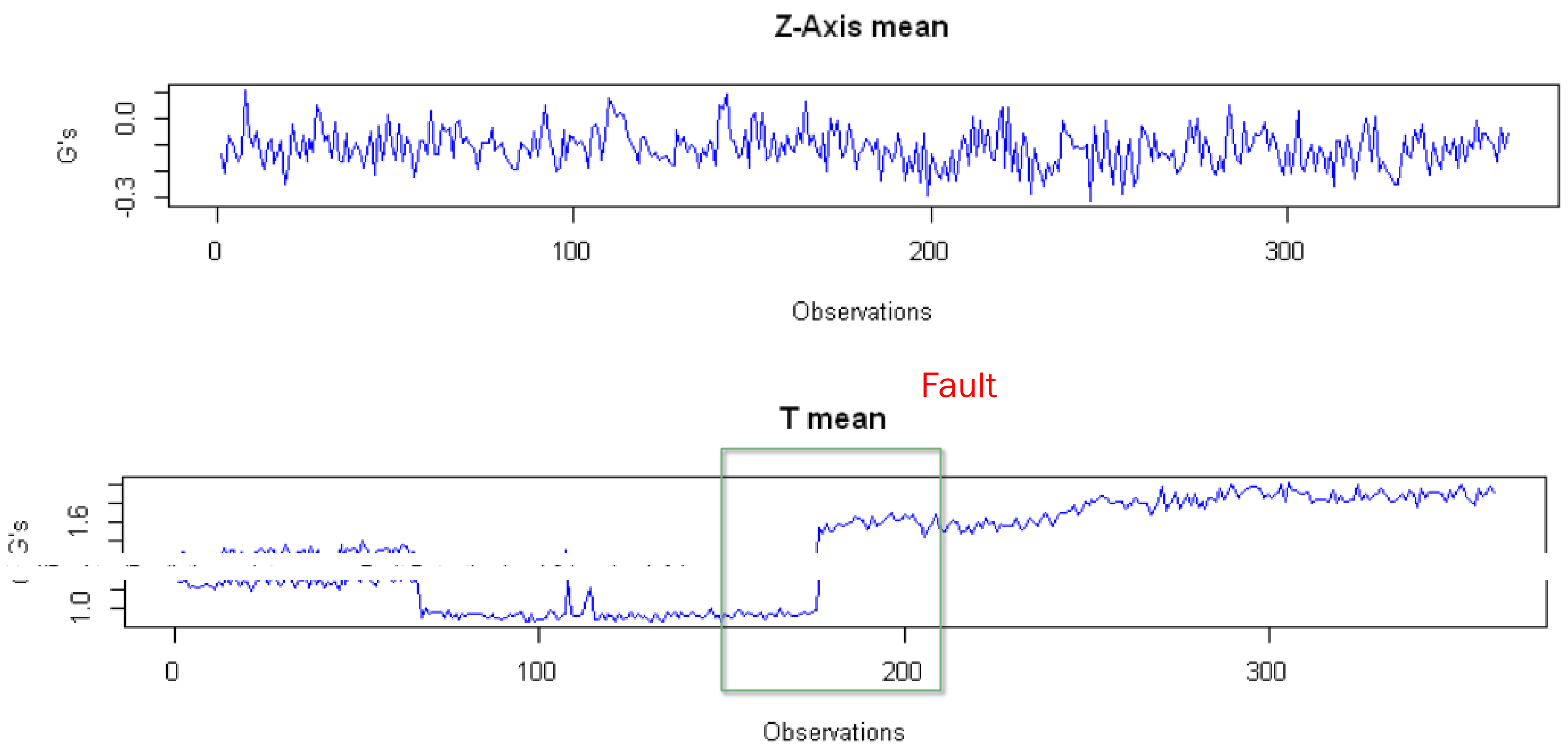
Data Aggregation and feature extract

In [5]:
```
file1$group = as.factor(round(file1$time))
file2$group = as.factor(round(file2$time))
file3$group = as.factor(round(file3$time))
file4$group = as.factor(round(file4$time))
#(file1,20)

#list of all files
files = list(file1, file2, file3, file4)

#loop through all files and combine
features = NULL
for (i in 1:4){
res = files[[i]] %>%
    group_by(group) %>%
    summarize(ax_mean = mean(ax),
              ax_sd = sd(ax),
              ax_min = min(ax),
              ax_max = max(ax),
              ax_median = median(ax),
              ay_mean = mean(ay),
              ay_sd = sd(ay),
```

group	ax_mean	ax_sd	ax_min	ax_max	ax_median	ay_mean	ay_sd	ay_min
0	-0.038164706	0.6594686	-1.2587	1.3821	-0.0955	-0.0682627451	0.7506785	-1.3892
1	-0.005806122	0.6325808	-1.6194	1.1943	-0.0015	0.0037908163	0.7819044	-1.5625
2	0.069845455	0.6665500	-1.4554	1.4667	0.1070	0.0744333333	0.8022922	-1.4800
3	0.011552525	0.5511310	-1.9254	1.2034	0.0675	0.0008262626	0.7894209	-2.0042
4	0.046688119	0.6426574	-1.7805	1.4837	0.0836	-0.0177594059	0.7510811	-1.6629
5	0.006678788	0.5780957	-1.4719	1.4355	0.0536	0.0013626263	0.7812245	-1.6293

In [6]:
```r
#plot data
par(mfrow=c(4,1))
plot(features$ax_mean, main="X-Axis mean", xlab="Observations", ylab="G's", type="l", col="blue")
plot(features$ay_mean, main="Y-Axis mean", xlab="Observations", ylab="G's", type="l", col="blue")
plot(features$az_mean, main="Z-Axis mean", xlab="Observations", ylab="G's", type="l", col="blue")
plot(features$aT_mean, main="T mean", xlab="Observations", ylab="G's", type="l", col="blue")
```




Z-Axis mean
G's
0.0
-0.3
0
100
200
300
Observations
Fault
T mean
G's
1.6
1.0
0
100
200
300
Observations

Fault Detection using PCA-T2 and SPE

Principal component analysis (PCA) is a mathematical algorithm that reduces the dimensionality of the data

T^2 Statistic is a multivariate statistical analysis

SPE also referred to a Q-statistic is the square prediction error.

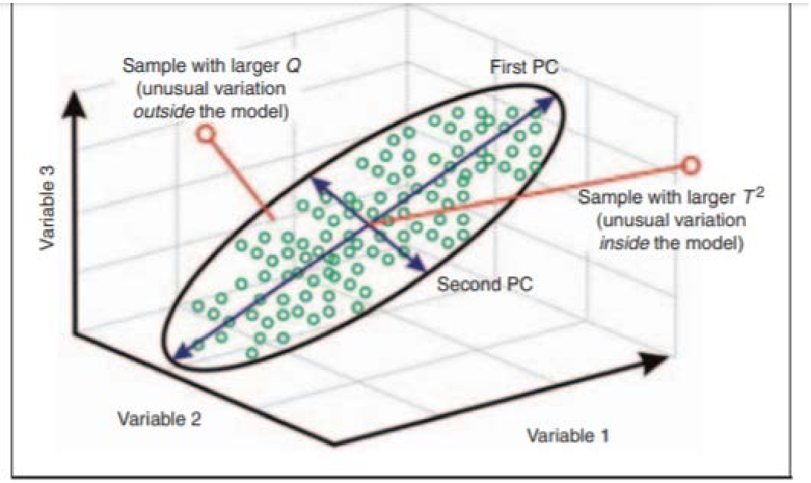


Figure 1. PCA model of a three-dimensional data set showing Q and T^2 outliers.[27]

In [7]:

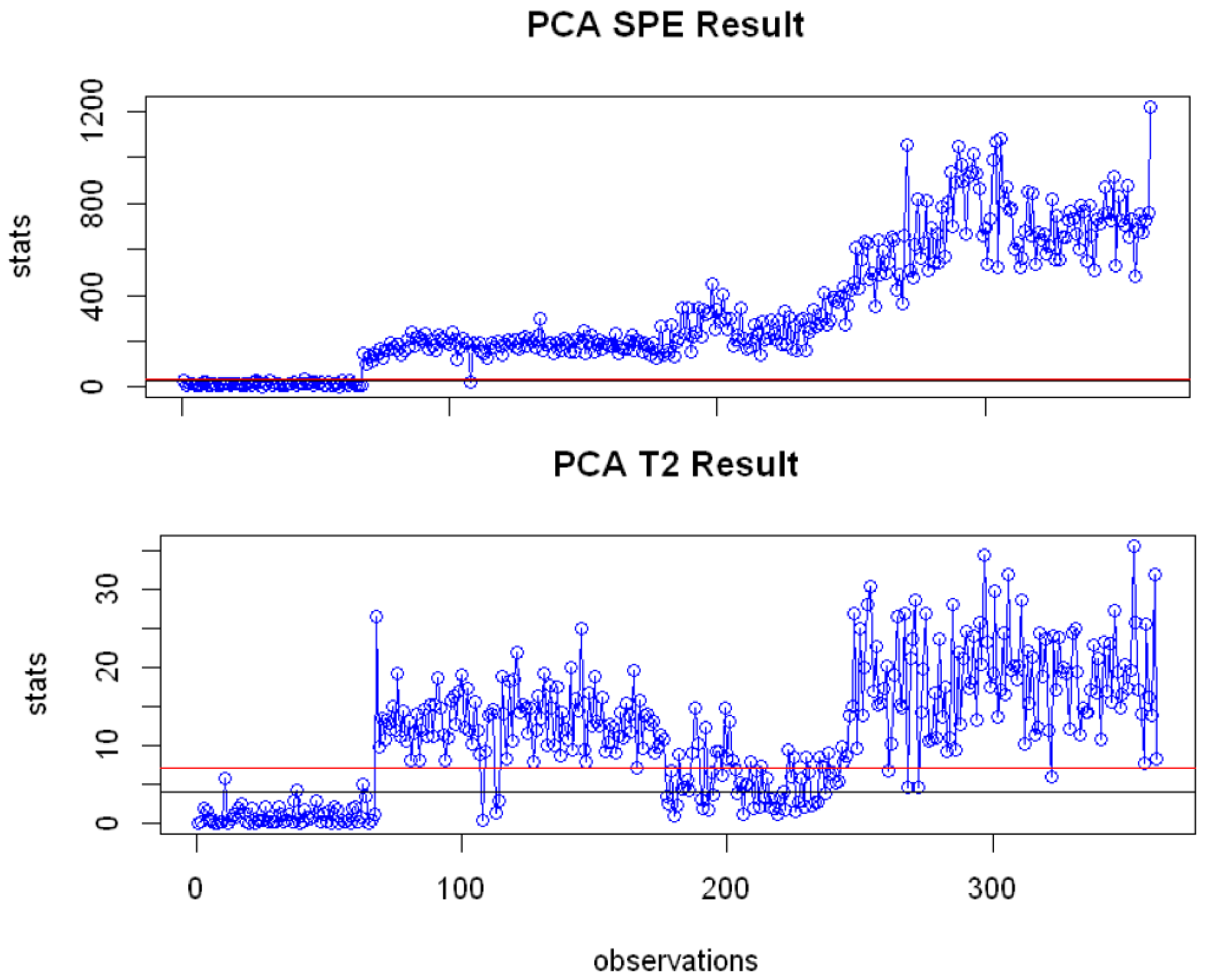
```
pca = function(train,test,variance, alpha,gamma) {

  #remove columns with zero variance
  train = train[sapply(train, function(x) length(levels(factor(x)))>1)]

  # calculate the pre-process parameters from the dataset
  preprocessParams = preProcess(train,
                                method=c("center", "scale"))
  # transform the dataset using the parameters
  traintransformed = predict(preprocessParams, train)
  testtransformed = predict(preprocessParams, test[,colnames(train)])

  #calibrate data for
  pca.model = mdatools::pca(x = traintransformed,
                            x.test = testtransformed
                            alpha
                            gamma
                            ncomp
```

In [8]:

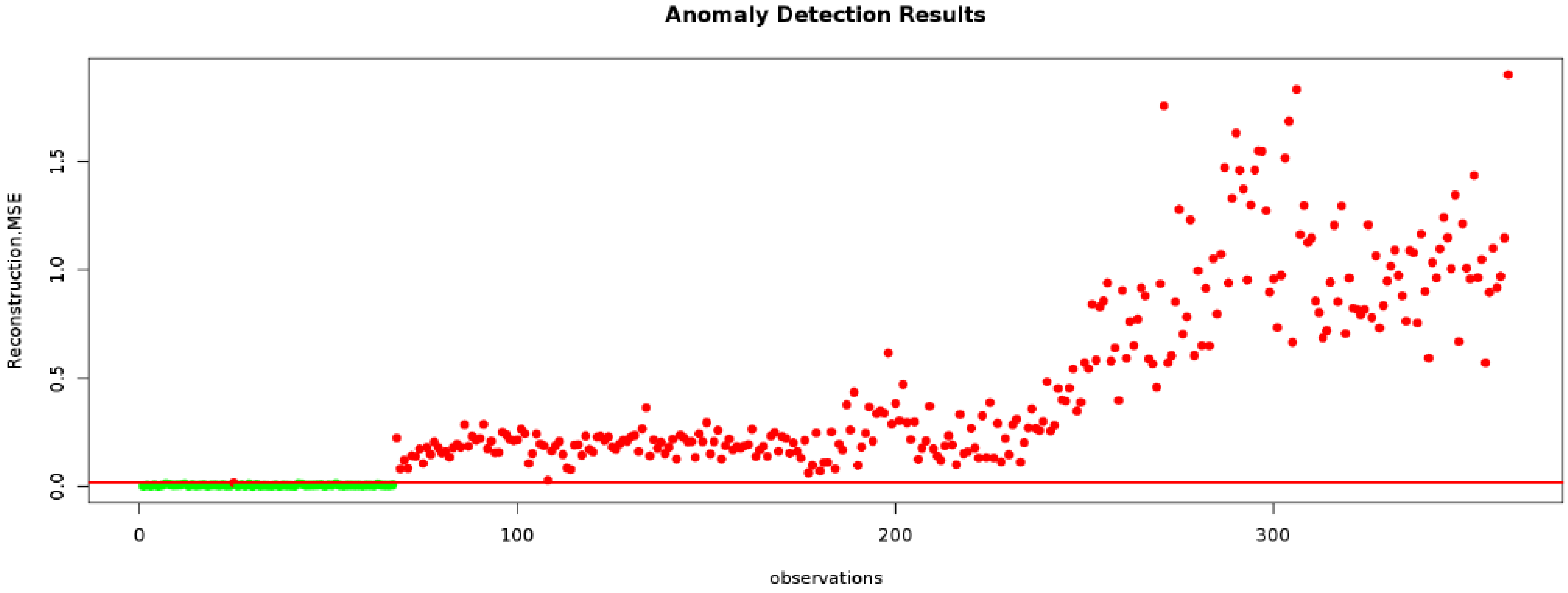
```
train = features[1:67,2:ncol(features)]
test = features[68:nrow(features),2:ncol(features)]
alpha = 0.05
gamma = 0.01
variance = 0.95

#call pca function
pca_result = pca(train,test,variance, alpha,gamma)
```

Coding Result

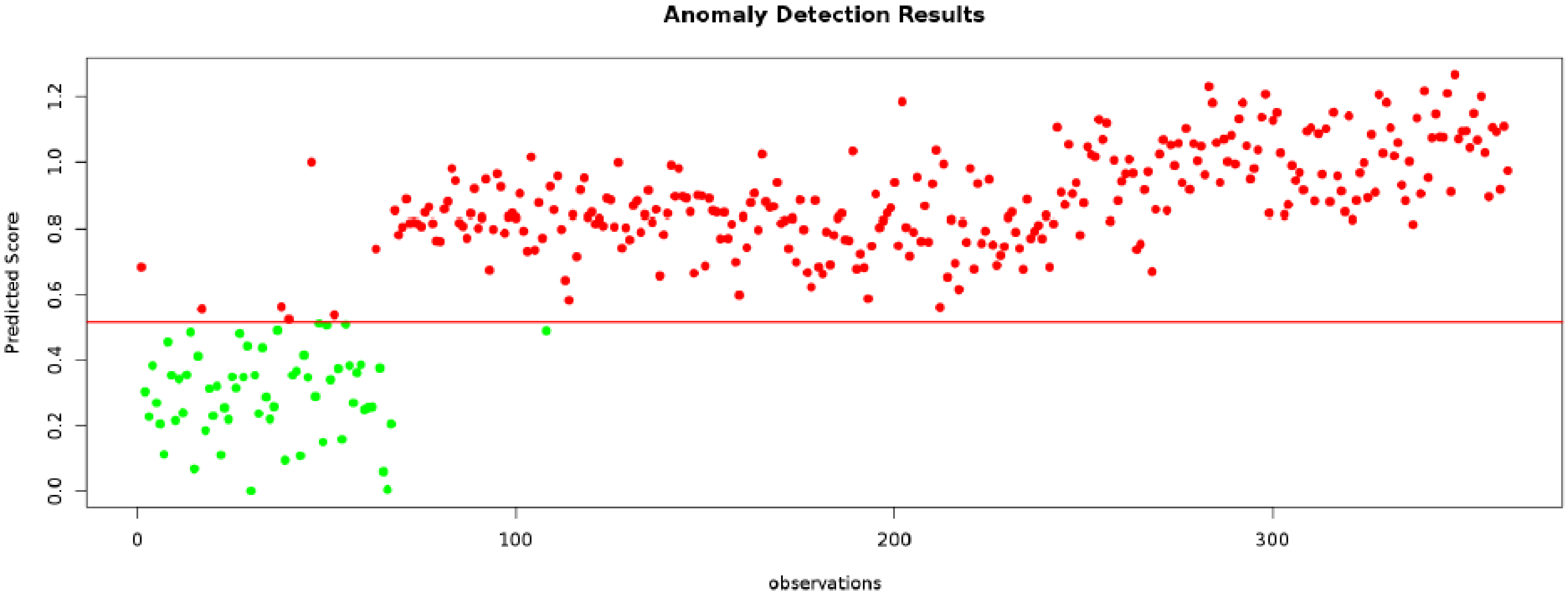
In [9]:
```
#plot results
par(mfrow=c(2,1))
plot(pca_result$T2stats, main="PCA T2 Result", ylab="stats", xlab="observations", col="blue", type="o")
abline(h=pca_result$T2critical, col="black")
abline(h=pca_result$T2outlier, col="red")

plot(pca_result$SPEstats, main="PCA SPE Result", ylab="stats", xlab="observations", col="blue", type="o")
abline(h=pca_result$SPEcritical, col="black")
abline(h=pca_result$SPEoutlier, col="red")
```

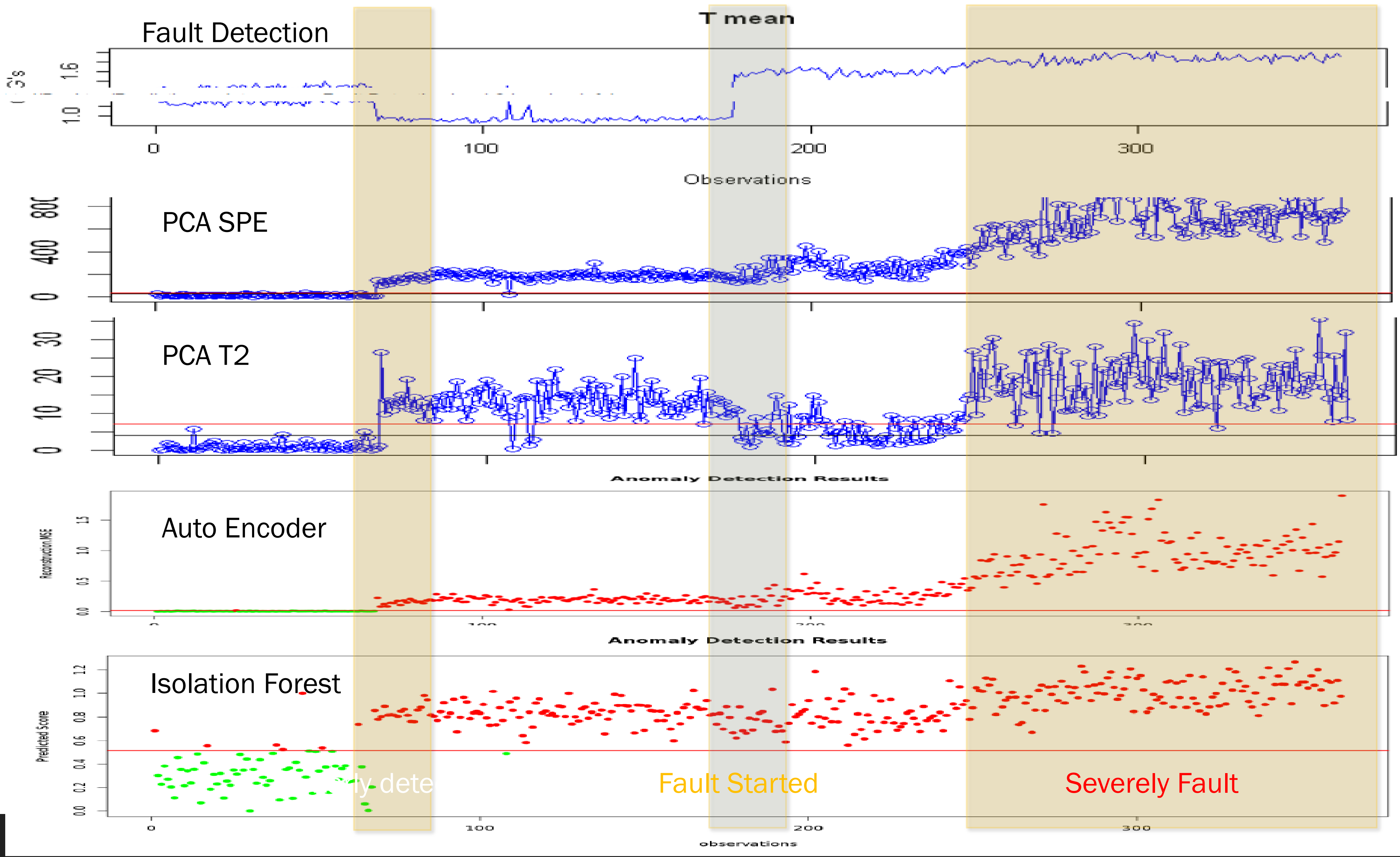

PCA SPE Result
stats
0
400
800
1200
PCA T2 Result
stats
0
10
20
30
0
100
200
300
observations

Auto Encoders for Anomaly Detection



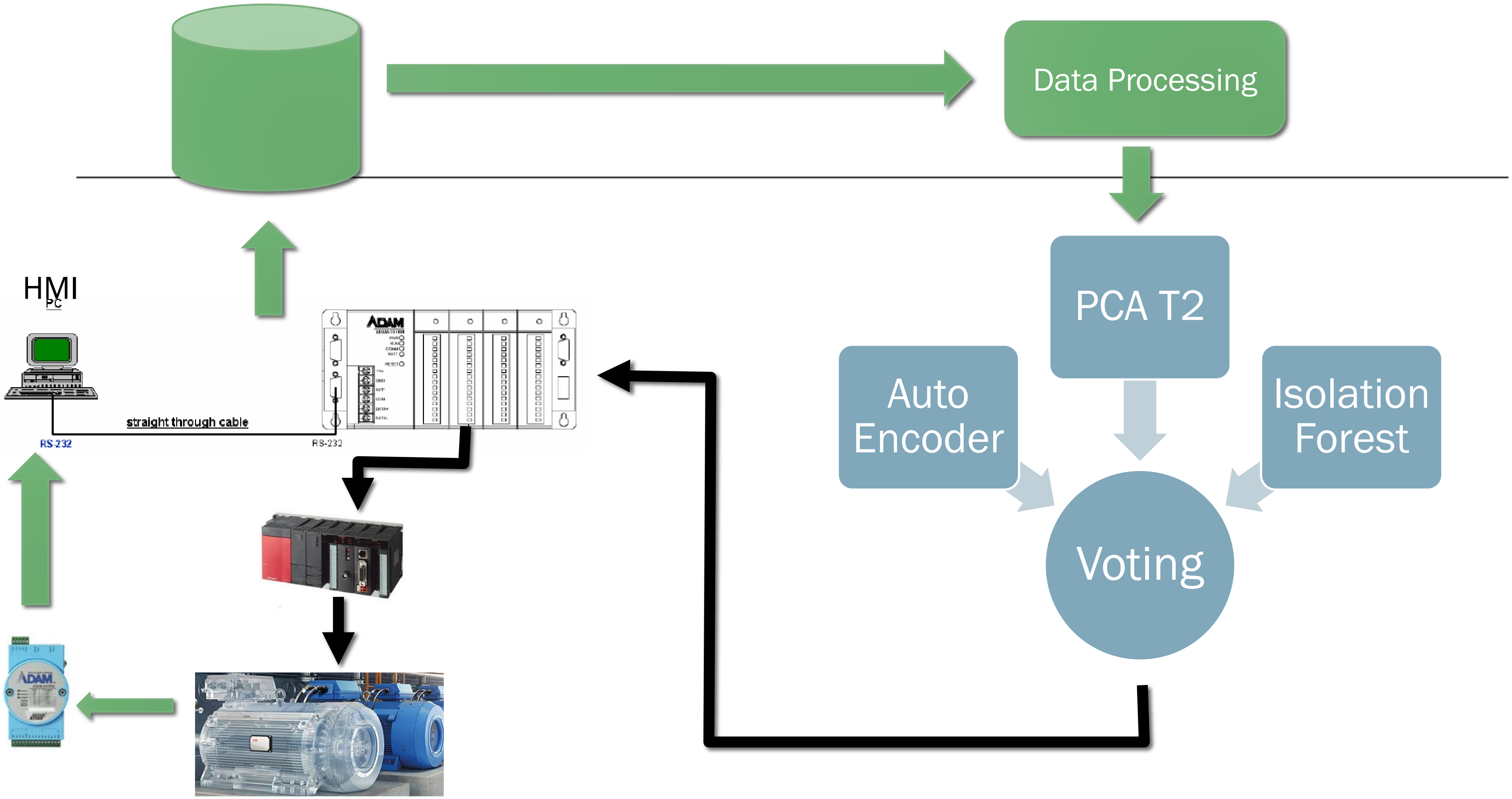
Isolation Forest




Fault Detection
T mean
Observations
PCA SPE
stats
PCA T2
stats
Anomaly Detection Results
Auto Encoder
Reconstruction MSE
Anomaly Detection Results
Isolation Forest
Predicted Score
Fault Started
Severely Fault
observations

Predictive Machine Monitoring System

Vibration Data/Current Consumption Data



Conclusion

Electric Motors used in large industrial scale are the key element of production process.

Preventive Maintenance may not response fast enough to protect the industrial work.

Predictive Maintenance has increasingly important to assist plant manager to cop with production shutdown caused from the motor failure.

Predictive Maintenance with AI could be a major tool to provide accuracy information for scheduling maintenance prior major failure occurs.

Fault Detection Techniques with Voting Algorithm have been tested to be a suitable tool of analysis the equipment.

To be integrated with the controller in the manufacturer, an agent like Advantech software could be utilized to manage the equipment to prevent its failure.