The University of Hong Kong

泛在感知信息化实时制造物联网平台
RFID-Enabled Real-Time Ubiquitous Manufacturing Platform

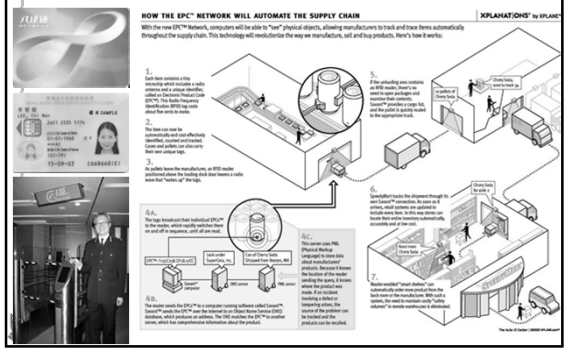
George Q. Huang

Department of Industrial and Manufacturing Systems Engineering

---

2

3rd wave of information revolution start with this smart card
第三次信息革命是由这张小卡引起-古老的新技术



3

Each of us must hold one of this card!



- 11 million Octopus cards are in circulation in Hong Kong.
- This little card has changed the way we travel to work places!
- This little card has changed the way public transports are operated!

4

追溯罪犯



追溯“非典”源头病人和感染黑点

5

Have you used this card during Christmas and New Year vacation?

- This little card has changed the way of our international travels!
- This little card has made Hong Kong's border control the most efficient and effective in the world!





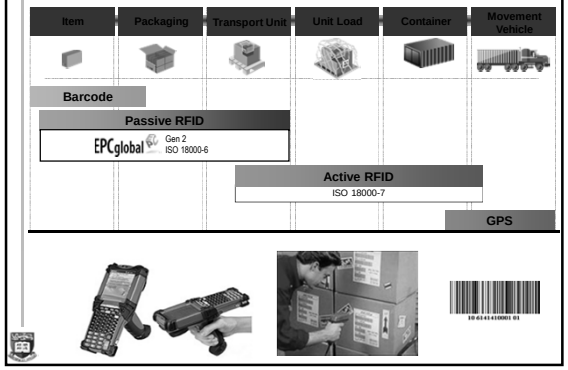
6

This little card has changed the way we use classrooms at HKU!

- Can you justify the project financially?
- Does the system contribute to efficiency or wastage reduction?
- Does the system support educational principle?



What would happen if everything has such a smart ID card?



Wal-Mart mandate

Nothing has happened in Wal-Mart shops! Why?

Phased approach for 25,000+ suppliers

2003	2004	2005	2006 & beyond
• June - Public announcement about use of EPC tags • November - Conference to clarify EPC tag policy	• June - Testing & pilots • Summit with suppliers for the initial (January 1, 2005) RFID effort	• January - Top 100 suppliers ship cases & pallets with EPC tags (Dallas DC) • February and later - Complete roll-out to other DC's for top 100 suppliers • Begin international roll-out	• All suppliers ship cases and pallets with EPC tags • Specialized item level tag testing

Milestones for the Wal-Mart RFID Mandate

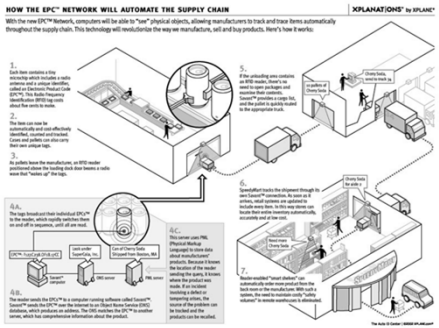
Processing Trade Enterprises in GPRD
珠三角國際加工貿易企業的重要性

- Over 100,000 PTEs in Guangdong
- Over 40,000 PTEs are Hong Kong-invested

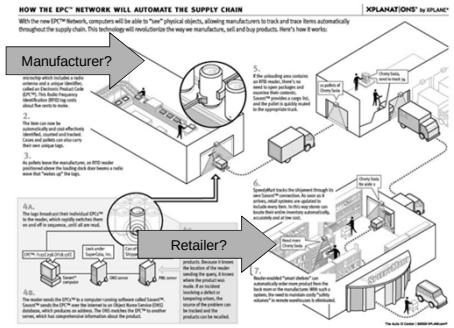


- Processing Trade Enterprises (PTEs)
  - Import raw materials, parts
  - Value-adding production
  - Export finished products to overseas markets
  - with tax exemption
  - low-cost but highly skilled labour
- Sources and Destinations of Global Supply Chain

Internet of Objects / Things (物聯網): RFID-Enabled Smart Supply Chains



Who spend time and money on tagging the objects? Each tagging costs HK$1-5.



Bottleneck Problems in Manufacturing

Shop-floor data are not real-time, inaccurate, incomplete, inconsistent.

製造信息不及時、不準確、不一致、不完整。

Manual data sheets are frequently damaged, lost, or misplaced.

手工紀錄經常受損、丟失、誤報。

Data collection is Non-value adding, Error-prone, Tedious, Time consuming.

數據採集費時而不增值、易出錯。



13

"Garbage in, Garbage Out"

*(2) Plans and schedules **cannot** be executed accordingly.*

(1) MRP/ERP need accurate timely data to make decisions.

Shop floor (e.g. Plant)

Machine status (e.g. breakdown running)

WIP & material stock information

Operator information

Scheduled information (e.g. dispatch list) + Shop order instructions

Enterprise Resource Planning (ERP) / Manufacturing Execution System (MES)

(3) Operators are too busy with jobs, no time to collect data.

15

Plan changes | **Supply changes** | **Design changes** | **Market changes**

ERP | **SCM** | **PDM** | **CRM**

Enterprise Application Systems

? ***Shop-floor Production Changes are not fed to ERP, CRM and SCM.***

? Supply Changes are not considered at shop-floor inventories.

? Engineering Changes are not considered at shop-floor for scrap or phasing out.

? Shop-floors are not promptly informed about Market Changes.

Schedule changes

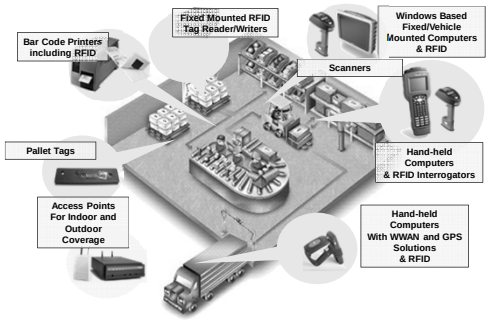
Status changes



Manufacturing Execution

17

Wireless / Ubiquitous Devices in Manufacturing Shopfloors



14

? Production orders cannot be directly imported from ERP to Scheduling system

ERP

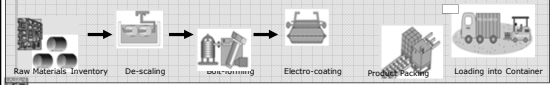
? Execution status at shop-floor are not fed back promptly for generating next order.

Scheduling

?
- Shop-floor inventories for raw materials, WIP items and finished products are not known.
- Machine statuses are unknown.

?
- Schedules and work orders cannot be executed at the shop-floor.

Shop-floor



16

Customs Declaration / Clearance

Online Customs Supervision

高透明度免檢、免驗 快速通關

Periodical Online Customs Inspection （中期核查）

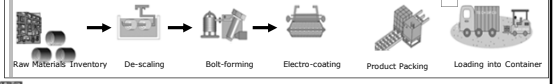
Enterprise Application Systems

ERP | SCM | WMS

Customs Management

Real-time information is not available for periodical online customs inspection

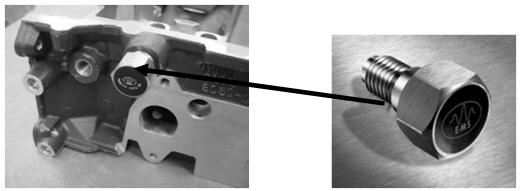
Work In Progress at Shop Floors
- Actual consumptions
- Actual stocks of raw materials, WIP items and finished goods



18

Automotive "Bolt Tag": common media to link supplier manufacturing data to end product

- Supplier may or may not be company owned
- Environment is extremely dirty (Oil / cutting fluids)
- Data needed in multiple, non-synchronous processes



19

"Bolt Tag" Integrates Car Engine Supply Chain

- **Forged part is born**
- **Cubing and primary machining completed**
- **"Bolt tag" installed on part**
- **Data recorded on "bolt tag" regarding S/N, Lot #, and Machine ID**
- **Detailed machine cutting**
- **Data regarding each step of the process recorded on the tag**
- **Head and Cam assembly process**
- **Finished head completed and ready for engine assembly**
- **Data regarding each step of the process recorded on the tag**
- **Head installed on engine final assembly**
- **Bolt tag removed and lifting eye installed in its place**

20

Wireless Manufacturing

Next-generation advanced manufacturing technology

- Deploy wireless devices and wireless networks
  - RFID or Auto-ID, Bluetooth, and ZigBee and Wi-Fi
- to typical manufacturing resources
  - materials and their containers / packages, tools and fixtures, workstations, and human operators
- to create so-called smart objects.
- Smart objects play vital roles in
  - automatic collection, processing and synchronization of real-time manufacturing data.

21

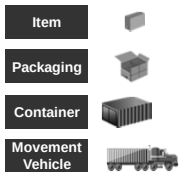
Active Smart Objects - Where are the RFID readers?

- RFID readers are deployed to "Value-adding points"
  - Working areas of All workstations
- Which frequency should be used for Smart Objects and why?
  - We tried both HF and UHF. Balance between cost and performance
    - UHF readers are much more expensive, but reading range is a bit too large – cover the area that should not be covered in the Lab space.
    - HF readers are cheaper, but its reading range is limited.
- Active Smart Objects are wirelessly networked.

22

Passive Smart Objects - What are tagged?

- Reusable containers
  - Packing boxes
  - Trays (for raw materials and WIP items)
  - Shipping containers
- Key components (Van body)
- All workstations
- Shop-floor operators



23

Majority efforts are spent on arguing

- ***Which frequency should be used: LF, HF, UHF, or Micro?***
- ***What should be tagged?***
- ***Where should RFID readers be deployed?***
- ***How to process large amount of primitive data into useful information?***

For Indoor and Hand-held

- ***Which technology solution is most appropriate depends on answers to these question.***
- ***Little time can be spared for industrialists to solve their business problems!***

24

What are we trying to do?

We are not trying to answer these questions:

- ***Which frequency should be used: LF, HF, UHF, or Micro?***
- ***What should be tagged?***
- ***Where should RFID readers be deployed?***
- ***How to process large amount of primitive data into useful information?***

Instead, we are trying to develop a technology solution that is independent of the answers to these questions,

So that the industrialists can focus on solving their business problems!

The University of Hong Kong

Our AUTOM Solution Roadmap

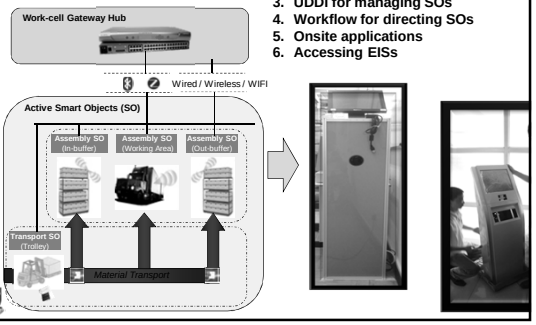
AUTOM - Ubiquitous Manufacturing Powered by Auto-ID Technologies

http://www.autom.hk/ 25

Work-cell Gateway

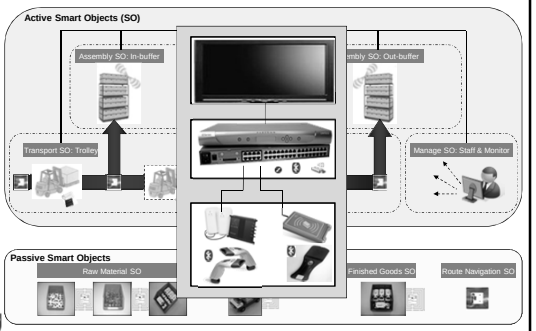
27

1. Standardize SOs
2. Hardware hub for hosting SOs
3. UDDI for managing SOs
4. Workflow for directing SOs
5. Onsite applications
6. Accessing EISs



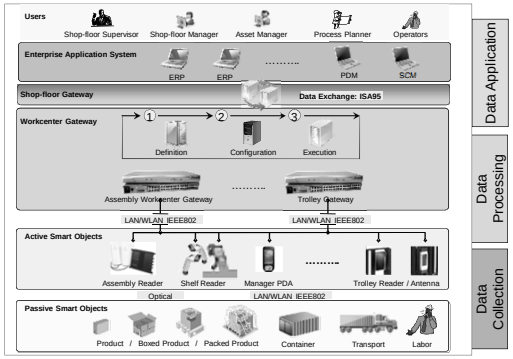
(2) Hosts heterogeneous Smart Objects

29



AUTOM: Ubiquitous Manufacturing Infrastructure

26

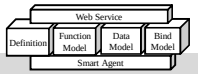


(1) Wrap/Execute Smart Object Agent/Service

28

This smart agent is a java class used to wrap the Driver of Auto ID devices, e.g. RFID Reader (Active SO) as web services.

Currently, the following devices have been wrapped as smart agent.
- Alien 's RFID Reader (UHF)
- ACS 's RFID Reader (HF)
- USB Camera (Bar-Code)

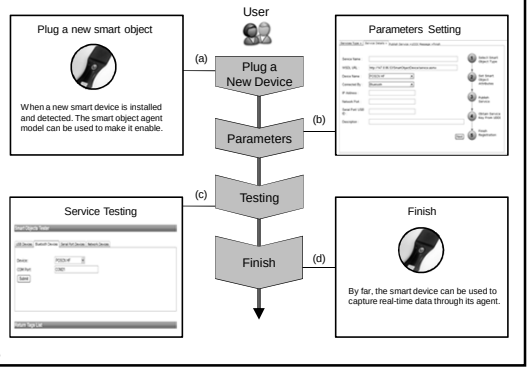



```
Public class Smart_Object_Agent {
    smart_object_agent () { //load_driver_and_port
        for(each driver){
            for(each port) {
              if (find) {
                successful;
              }
            }
    }
    smart_object_agent (String smart_object_config.xml) {
        load_driver ();
    }
    public String network_read_tag(String reader_id, String antenna_id)
    public void network_write_tag(String reader_id, String antenna_id, String write_text)
    public String port_read_tag(String reader_id, String antenna_id)
    public void port_write_tag(String reader_id, String antenna_id, String write_text)
}
```



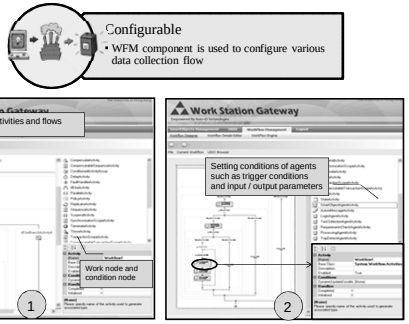
(3) Define SO Services

30



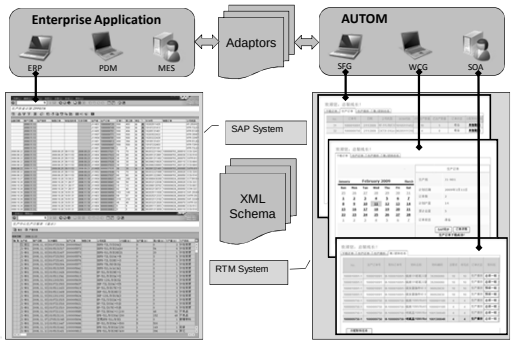
31

(4) Configure and Manage Workflow



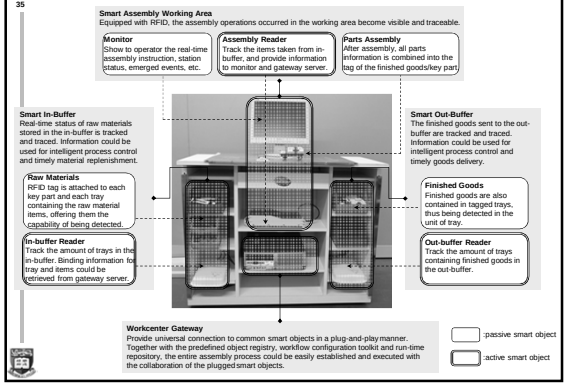
33

(6) 企业信息源对接服务
Access / adapt remote Application Data sources



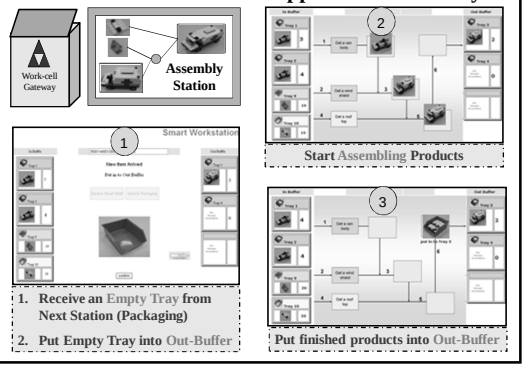
35

Stationary Smart Work-Cell: Assembly Workcenter



32

(5) 工作单元可视化服务
Execute Real-time onsite application - Visibility



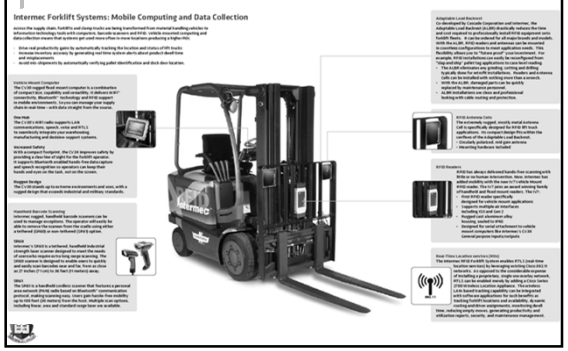
34

AUTOM Gateway won GS1HK Silver Award

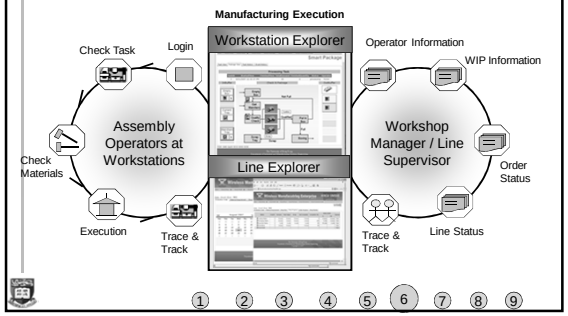


36

Mobile Smart Work-Cell: Forklift



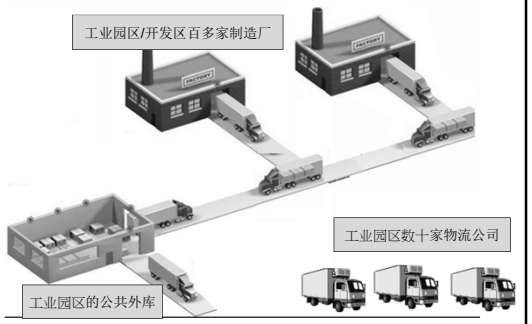
Real-time “Work” explorers for shop-floor execution



What have we learnt?

- There are differences between RFID solutions between manufacturing and supply chain applications.
- “Plug and Play” Self-Configurable and Scalable.
  - Smart object level
  - Gateway level
- False expectations, human problems and business process reengineering
- Three “high” problems (“三高問題”)
  - High cost
  - High risk
  - High technical skill

工业园区物联网意义重大：从制造大国科学发展漫向制造强国



The University of Hong Kong

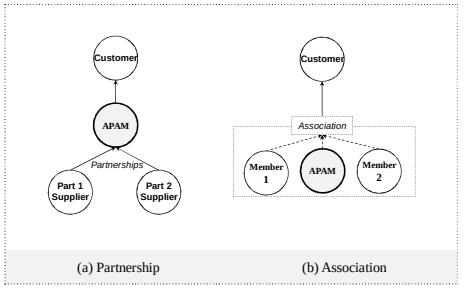
Insights and Lessons

Project team
Shopfloors
Manufacturers

“Three high problems (三高問題)”

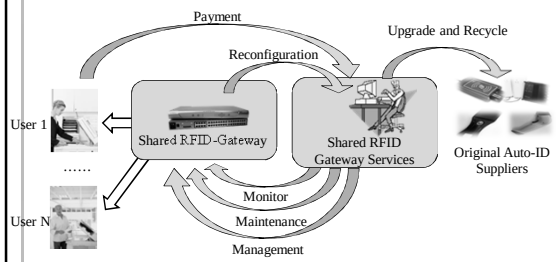
- RFID solutions suffer from “Three high problems (三高問題)”:
  - high cost（成本高）,
  - high risk（風險高）and
  - high technical level（技術門檻高）
- Causes for “Three high problems (三高問題的因由)”
  - RFID devices are still expensive
  - RFID variety is too wide to manage
  - RFID know-hows are not easy to master – specialist skills
- We need a new business model and a suitable technology solution that solve industrial problems.

Two types of Automotive alliances



43

RFID Product Service System
- New Business Model for New Technology Deployment



45

Pilot Project 1

RFID-based Shop-floor WIP Management System

- Guangdong ***** Air Conditioning CO., LTD.



- **4th largest**
- **20,000 daily output**

47

1. Problems in Warehouse









- 5,000+ types of raw material
- 49 warehouses

inventory management is:
- error-prone
- inefficient
- a waste of manpower

The University of Hong Kong

Industrial pilots

AUTOM - Ubiquitous Manufacturing Powered by Auto-ID Technologies

http://www.autom.hk/ 44

46

Onsite Pilot Study



48

2. Problems in 15 Pre-assembly Lines





unclear WIP information → redundant WIP → resources waste

unclear WIP information → inadequate WIP → final assembly suspended

3. Problems in Final Assembly Line



production plan

?

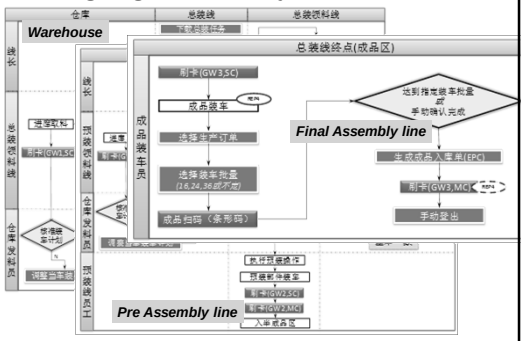
order status



order progress status not instantly fed back to the ERP system

timely adjustment of production plans impossible

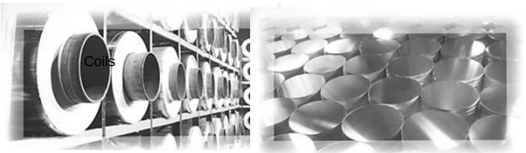
Working Logic of Gateway 1



@ Pilot Project 2

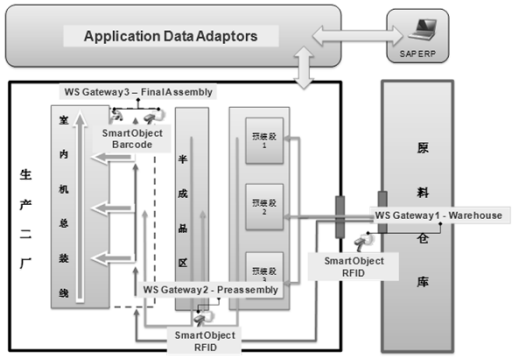
~~RFID-based Real-time Scheduling and WIP Management System~~

~~-Hong Kong ***** Aluminum Limited~~



The largest aluminum circle producer in the world

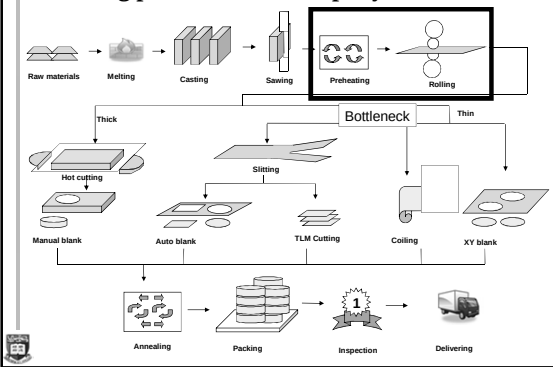
Solution Framework



System Interface



Working process of the company



55

Problems

- Limited spaces
  - Only 350 spaces for WIP, raw and finished products
- Production scheduling is complex
  - Two-stage hybrid flowshop scheduling with batching and blocking processing. The setup time is sequence-dependent.
- Lack of real-time raw material inventory data
  - The input material (aluminum slabs) is produced by casting mill and the location of inventory spread around in the factory. The manual checking is time consuming.
- Lack of real-time shop floor production data
  - The production report is delayed. In some unusual condition, there is no chance to adjust the scheduling according to practical situation.

57

GA based E-Scheduling system



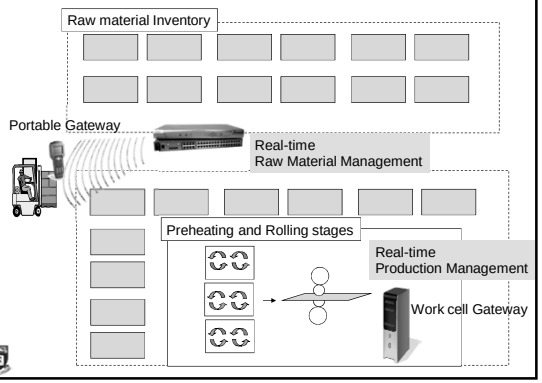
59

Collaborative Manufacturing

- **Step 1: Subcontracting / outsourcing**
  – How to select most suitable contractors to outsource
- **Step 2: Collaborative planning and scheduling among partners**
  - Depend on individual capability, capacity and loading
- **Step 3: Real-time production coordination**

56

Application of portable Gateway and Work cell Gateway

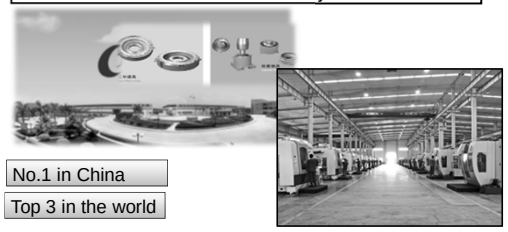


58

Pilot Project 3

~~RFID-based Collaborative Production Management System~~

At ~~*****~~ Tyre Mould Manufacturer



No.1 in China

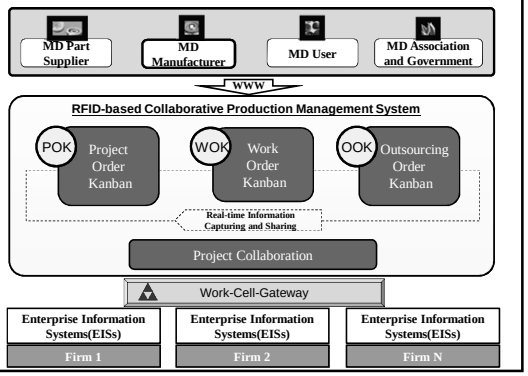
Top 3 in the world

60

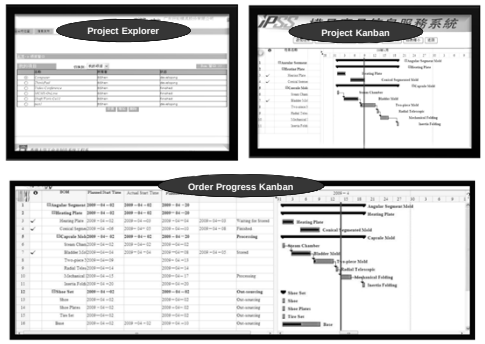
Step 1: Collaborative Outsourcing



Step 2: Collaborative progress monitoring



Step 3: Collaborative production coordination



The University of Hong Kong

What are the impacts or implications of Ubiquitous Manufacturing on basic research?

What are theoretical challenges?
What are scientific issues?
What are academic contributions?

A small step to reduce the gap between theory and practice

- Companies worked with university researchers and/or consulting companies with little success
  - Industrial problems require substantial rigorous research.
  - Industrial problems cannot be solved theoretically.
- Decision models could be much simplified to a solvable level
  - Existing solution algorithms can now be used to solve real-life industrial problems.
  - Solution algorithms would become much faster.
  - Some theoretical efforts would become obsolete?
- Ubiquitous Manufacturing System is less stochastic and more deterministic!
  - Standard operation times have 5-20% variation
  - Job arrivals are real-time
  - Disturbances are real-time
  - Situations are more predictable if still stochastic.

Uses of Wireless / Ubiquitous Manufacturing

- Paperless process improves correctness and efficiency in data and material transactions.
- Track and trace enterprise assets (Man, machine, materials and orders).
- Enhance the workers' sense of responsibility.
- Real-time project progress Kanbans improve collaboration among outsourcing partners.
- Visualize and simplify operations and decisions
  what you do is what you see and what you see is what you do.
- In-advance warning on wrong arrival, departure, delivery of materials.
- Discover bottleneck, diagnose process errors, adjust schedules for unexpected disturbances.

The University of Hong Kong

