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EFS
ÉTABLISSEMENT FRANÇAIS DU SANG

IPIC 2016

PI-Based Automated Diagnosis: The Blood Supply Chain Perspective

Quentin SCHOEN, Franck FONTANILI, Matthieu LAURAS, Sébastien TRUPTIL and Anne-Ghislaine ANQUETIL

Atlanta, 29/06/2016

Context of the research work

The Blood Supply Chain: Complex?

- High diversity
- Fresh products
- Traceability requirements
- Short lifespan
- High uncertainty

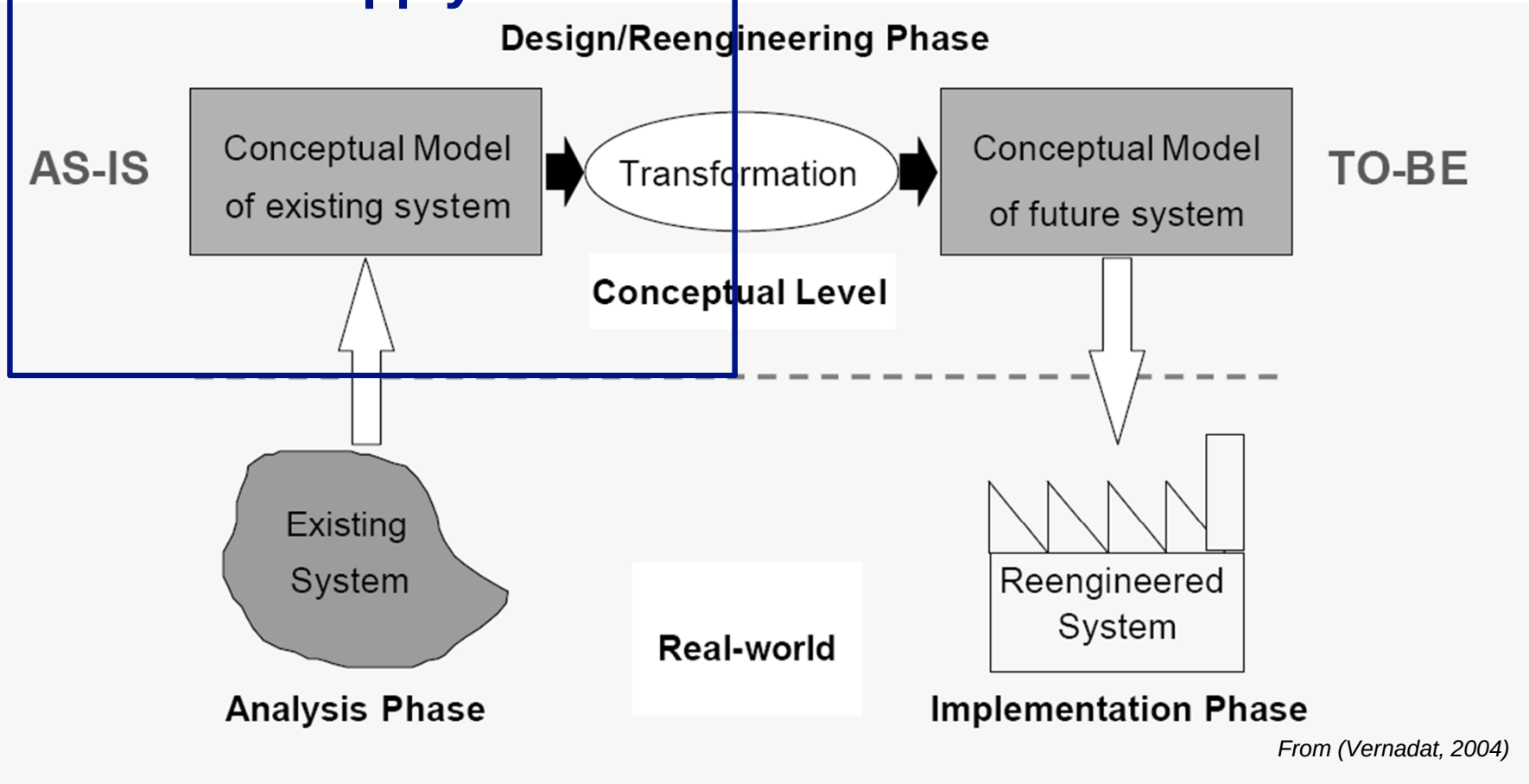
Our research objectives:

This paper:

- Supporting the blood supply chain re-engineering
- Improving the management of this supply chain

The re-engineering approach

How to automatically do this in a Supply Chain?



From (Vernadat, 2004)

How to diagnose the Blood Supply Chain?

For each item:

Added Value Activities? Inventories? Leadtimes? Distance?...

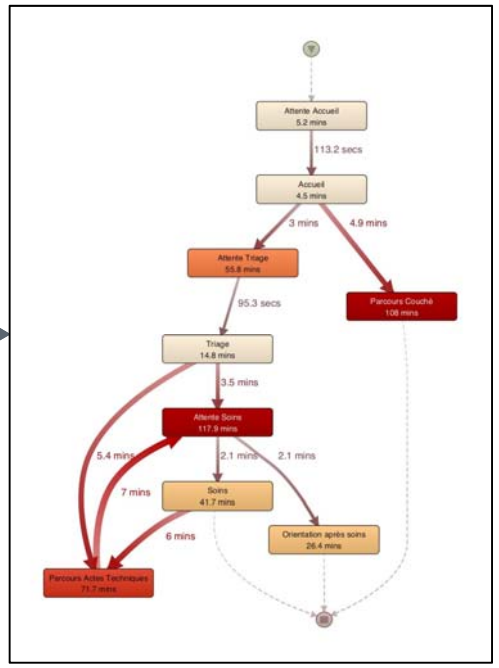
Our Approach: The Process Mining®

Log File
(one line = one event)

ID Patient	Heure Début	Activité
143	19/04/14 12:07	Accueil
140	19/04/14 12:10	Triage
144	19/04/14 12:12	Accueil
133	19/04/14 12:12	Soins
141	19/04/14 12:23	Triage
145	19/04/14 12:26	Accueil
145	19/04/14 12:35	Parcours Couché
142	19/04/14 12:40	Triage
129	19/04/14 12:43	Orientation après soins
141	19/04/14 12:49	Soins
143	19/04/14 12:54	Triage
146	19/04/14 12:56	Accueil
147	19/04/14 13:02	Accueil
144	19/04/14 13:06	Triage
148	19/04/14 13:08	Accueil
149	19/04/14 13:12	Accueil
148	19/04/14 13:15	Parcours Couché
150	19/04/14 13:20	Accueil
146	19/04/14 13:21	Triage
144	19/04/14 13:25	Parcours Actes Techniques
132	19/04/14 13:29	Orientation après soins
150	19/04/14 13:30	Parcours Couché
151	19/04/14 13:31	Accueil
147	19/04/14 13:33	Triage
152	19/04/14 13:41	Accueil
149	19/04/14 13:47	Triage
153	19/04/14 13:48	Accueil
146	19/04/14 13:49	Soins
136	19/04/14 13:49	Orientation après soins
152	19/04/14 13:50	Parcours Couché
147	19/04/14 13:51	Parcours Actes Techniques

Process Mining

Process Mapping

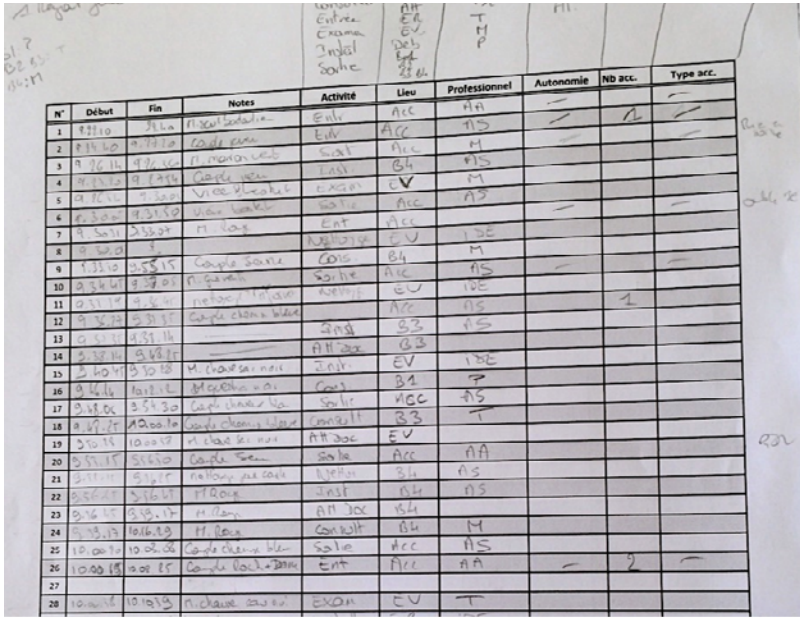


Difficulties and risks: Log file

- Accuracy, completeness, availability,… of data

How to get a log file? - Solution 1 = "hand made"

- **Field observations and "manual" data gathering**



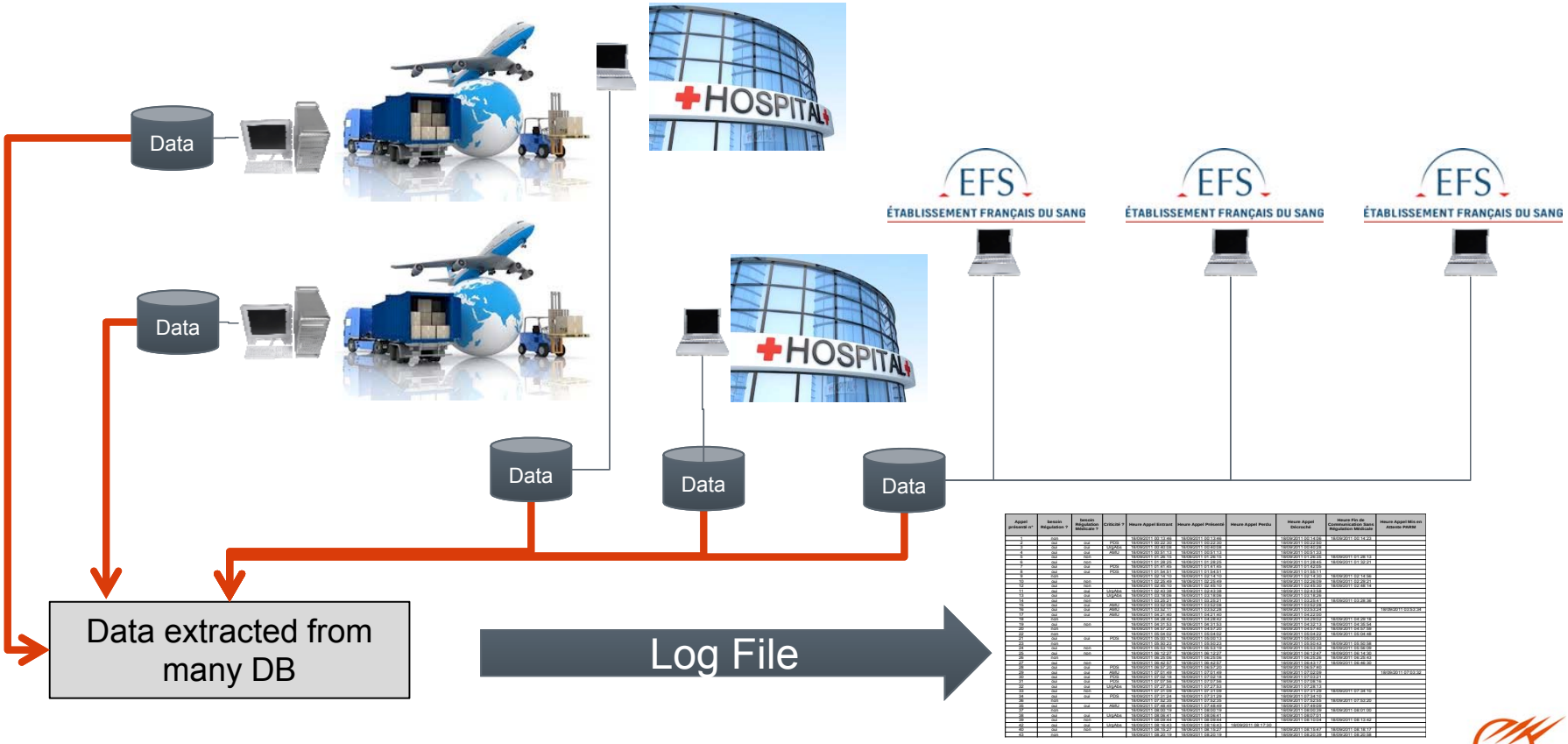
N°	Début	Fin	Notes	Activité	Lieu	Professionnel	Autonomie	Nb acc.	Type acc.
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									

- **Difficulties, risks**
  - Non-exhaustive
  - Misinterpretation
  - Inaccurate measurements
  - Time spent

- **Next step: Paper to Computer (worksheet file)**

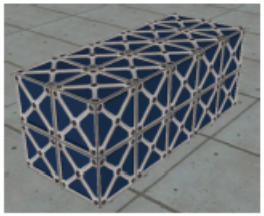
How to get a log file? - Solution 2 = "DB made"

- **Data extracted from IT Systems**

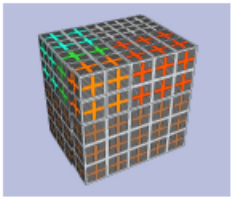


How to get a log file? - Solution 3 : "PI-container made »

- **PI-containers principles to be designed & applied to the Blood Supply Chain**
  - Active
  - Standard



T-container
World standard
Easy to transport and handle
Capable of sustaining tough external conditions
Stackable as cargo containers



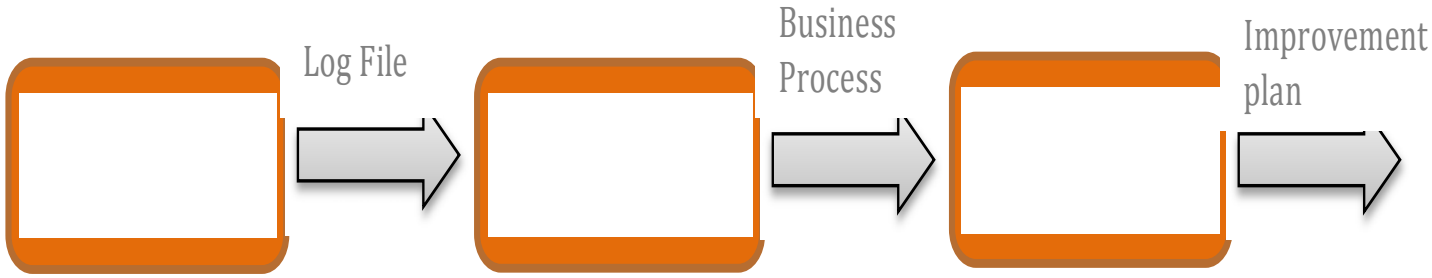
H-container
World standard
Easy to handle
Capable of sustaining tough handling conditions
Stackable 2,4m minimum

P-container
World standard
Easy to insert and extract
Capable of protecting the product
Stackable 1,2m minimum

From (Montreuil, 2015)

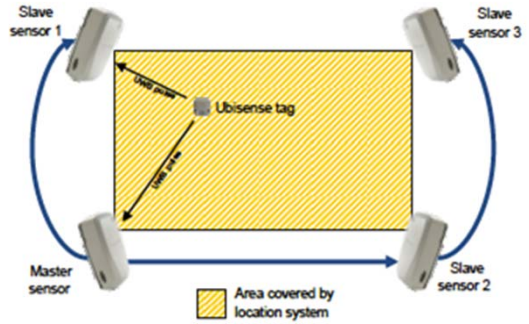
Our proposal

- **Coupling Physical Internet & Process Mining to automatically diagnose Supply Chains**



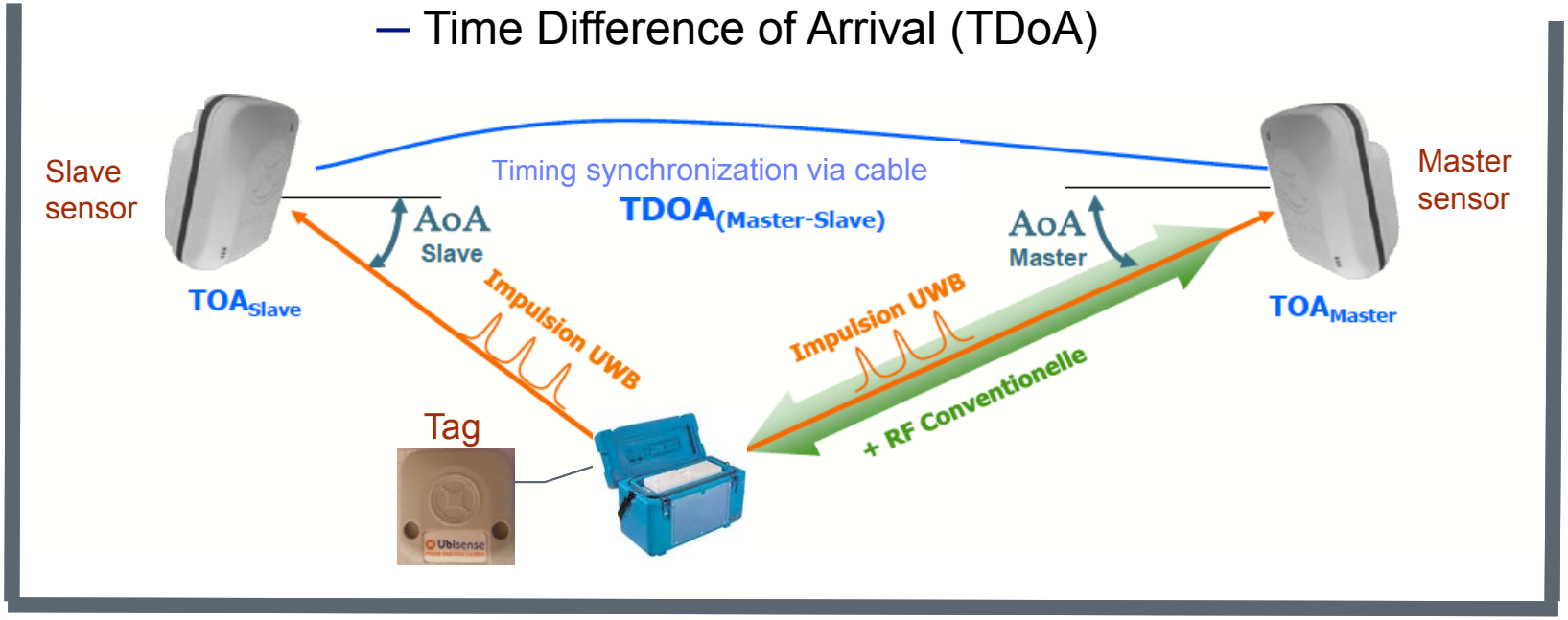
- **How to design the PI-Containers?**
  - For indoor purposes?
  - For outdoor purposes?
  - For mixed purposes?

Indoor Experiment with RTLS (Real Time Location System)



RTLS for Fresh H-Containers

- **Using Active Radio Fequency Tags (UWB)**
- **UWB signal received by sensors (at least 2)**
- **Tag position (x,y,z) can be calculated from:**
  - Angle Of Arrival (AoA)
  - Time Difference of Arrival (TDoA)



Experiment

Collection Centers

CC_A

CC_B

CC_C

CC_D

...

Screening Center

Hub

Processing Center

Distribution Centers

DC_A

DC_B

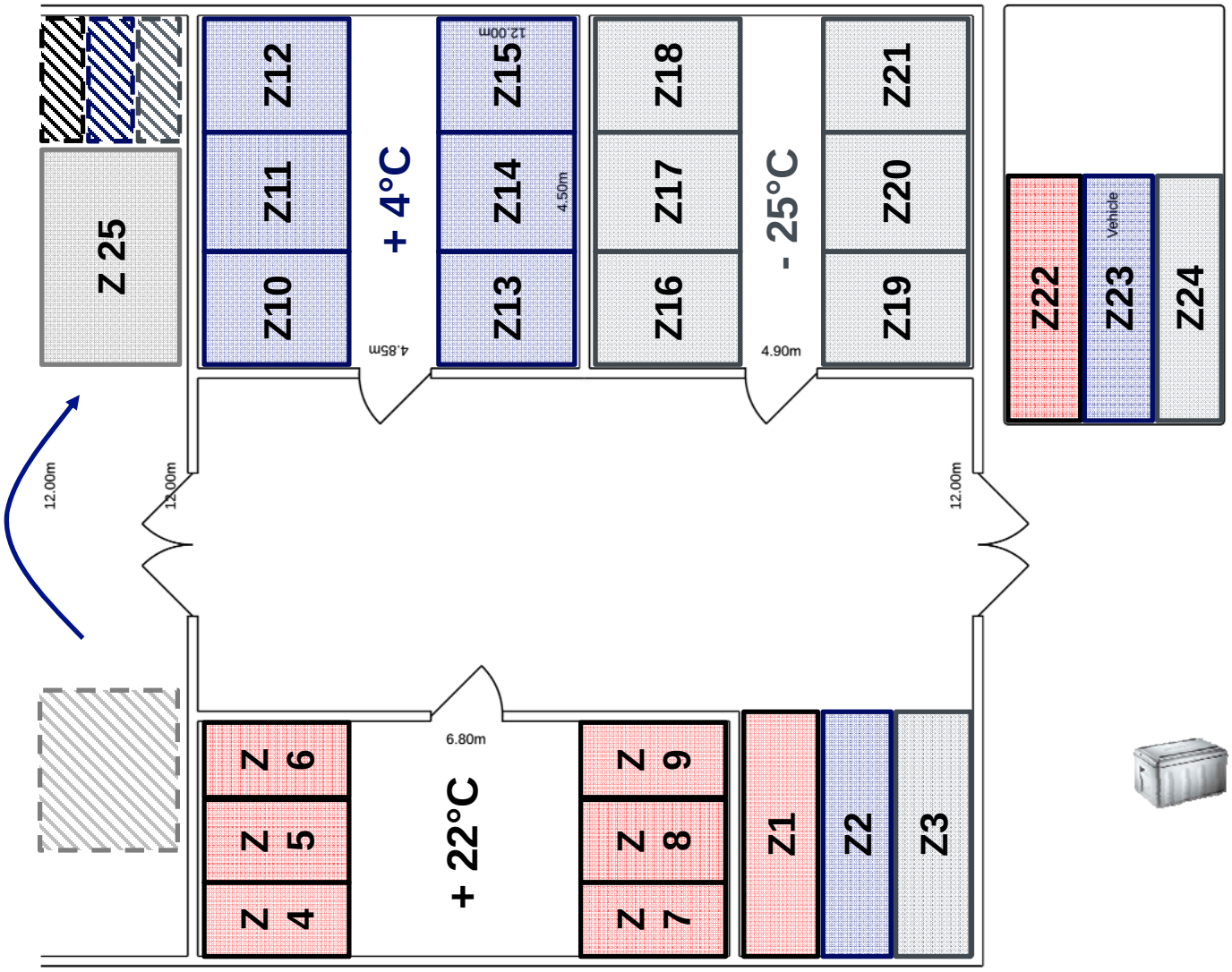
DC_C

DC_D

...

Key: → Fresh blood pouches and samples

⇢ Validated End Products



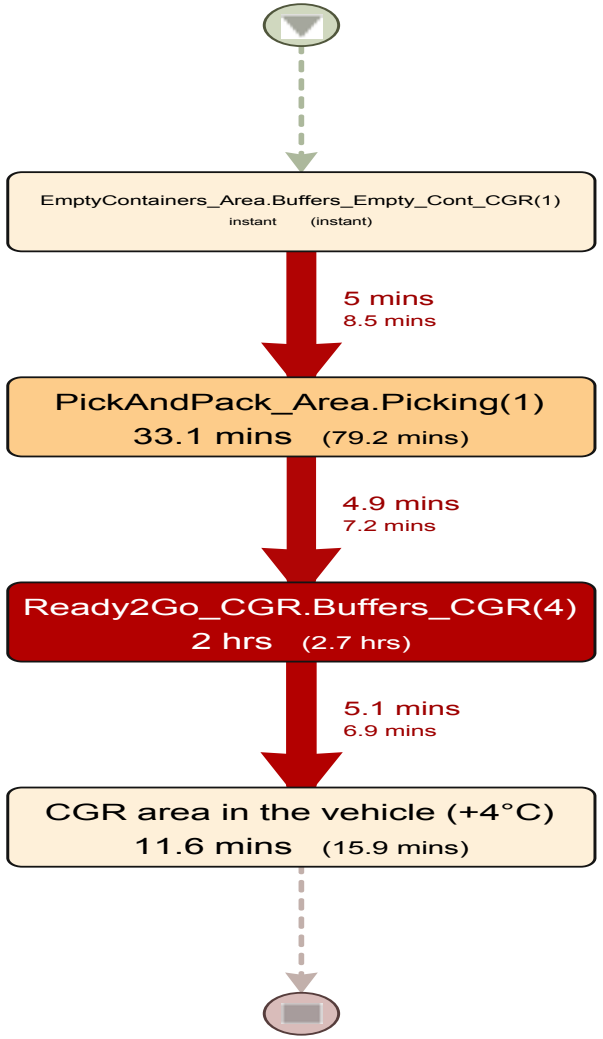
Event #	ID #	Activity	Timestamp
1764	2098	Vehicle departure	26/10/2015 20:33:34

Exploitation

Event	Container ID	Activity	Timestamp start	Timestamp end
8	2004	EmptyContainers_Area.Buffers_Empty_Cont_CGR(1)		26/10/2015 8:12
31	2004	PickAndPack_Area.Picking(1)	26/10/2015 8:16	26/10/2015 8:48
49	3007	EmptyContainers_Area.Buffers_Empty_Cont_PFC(1)		26/10/2015 9:09
62	3007	PickAndPack_Area.Picking(1)	26/10/2015 9:14	26/10/2015 9:20
191	2004	Ready2Go_CGR.Buffers_CGR(1)	26/10/2015 8:53	26/10/2015 12:06
214	2004	CGR area in the vehicle (+4°C)	26/10/2015 12:12	26/10/2015 12:21
231	3007	Ready2Go_PFC.Buffers_PFC(2)	26/10/2015 9:24	26/10/2015 12:36
244	3007	PFC area in the vehicle (-25°C)	26/10/2015 12:43	26/10/2015 12:46
1395	2191	EmptyContainers_Area.Buffers_Empty_Cont_CGR(1)		27/10/2015 15:47
1413	2191	PickAndPack_Area.Picking(1)	27/10/2015 15:51	27/10/2015 16:39
1493	1077	EmptyContainers_Area.Buffers_Empty_Cont_CPA(1)		27/10/2015 18:16
1518	1077	PickAndPack_Area.Picking(1)	27/10/2015 18:20	27/10/2015 19:03
1602	2191	Ready2Go_CGR.Buffers_CGR(3)	27/10/2015 16:43	27/10/2015 19:55
1625	2191	CGR area in the vehicle (+4°C)	27/10/2015 20:00	27/10/2015 20:12
1703	1077	Ready2Go_CPA.Buffers_CPA(6)	27/10/2015 19:07	27/10/2015 20:58
1727	1077	CPA area in the vehicle(+22°C)	27/10/2015 21:04	27/10/2015 21:23
4278	3339	EmptyContainers_Area.Buffers_Empty_Cont_PFC(1)		30/10/2015 19:45
4366	3339	PickAndPack_Area.Picking(1)	30/10/2015 19:50	30/10/2015 20:12
4471	3339	Ready2Go_PFC.Buffers_PFC(6)	30/10/2015 20:17	30/10/2015 21:11

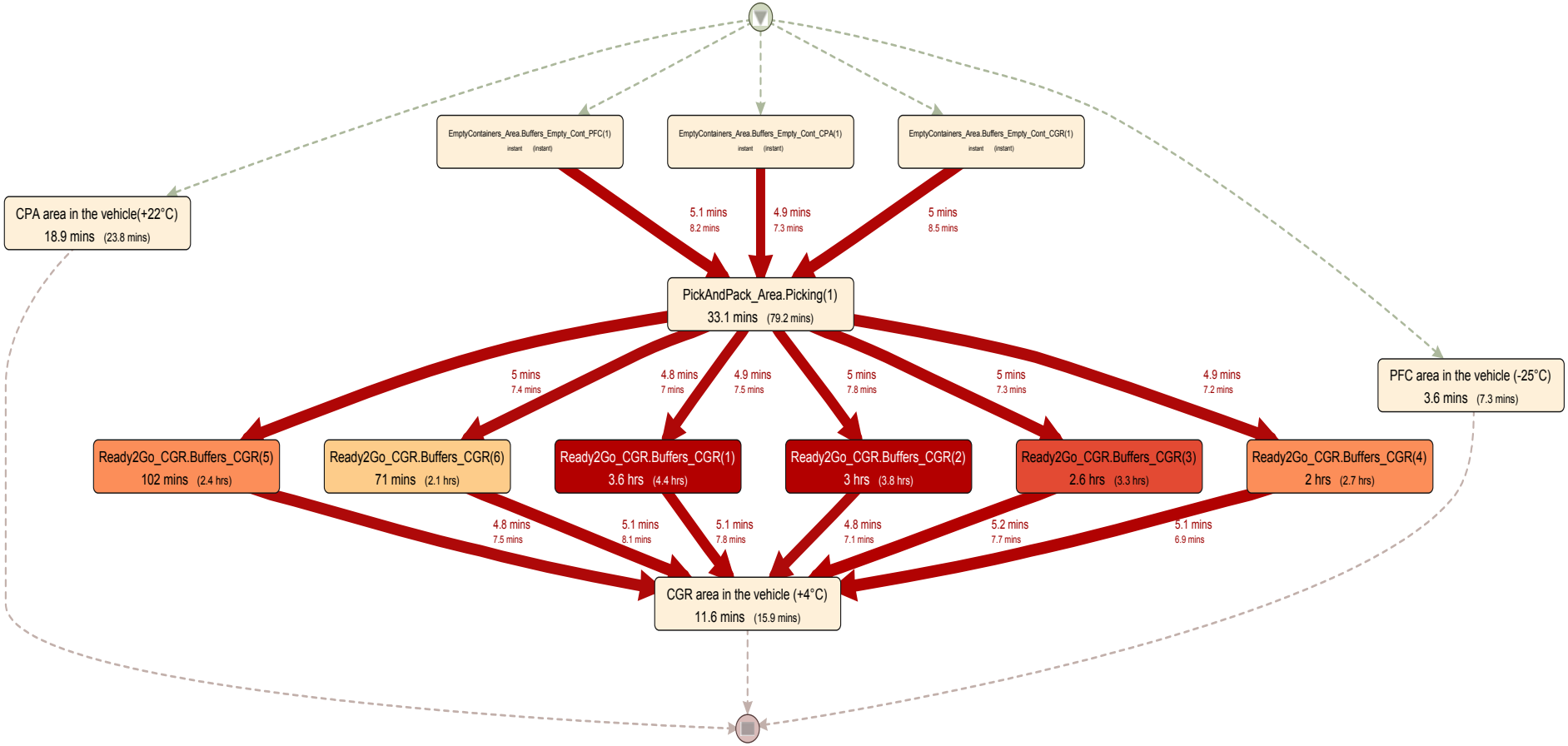
Obtained Log File

Using DISCO®



Deduced Business Process Map

Exploitation



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Conclusion and Perspectives

- **A starting research work to support the improvement of Supply Chains by coupling Physical Internet and Process Mining**

- **Many things still have to be done:**
  - Design of PI-Containers for Fresh Supply Chains
    - Indoor / outdoor
  - Use the PI-principles to support the management of Fresh Supply Chains in real-time
    - Agility
  - Larger experiments
    - Validation

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Questions ?

matthieu.lauras@mines-albi.fr

$F^2\pi$: A Physical Internet Architecture for Fresh Food Distribution Networks

Amitangshu Pal and Krishna Kant

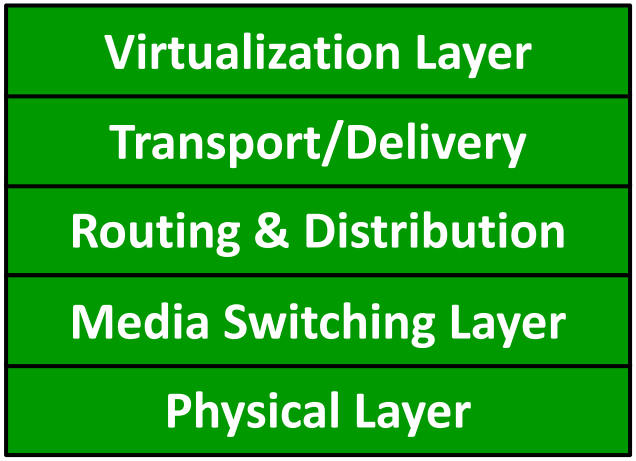
Computer and Information Sciences

Temple University

TEMPLE UNIVERSITY

Background

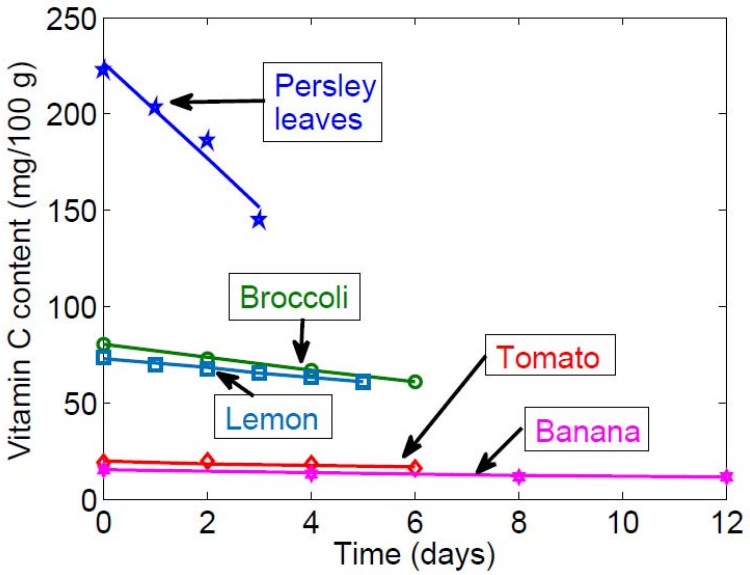
- Fresh Food Physical Internet ($F^2\pi$)
  - An extension of Physical Internet (PI)
- Motivation
  - 40% of fresh food wasted
  - Transportation efficiency ~15% → huge and avoidable carbon footprint
  - Long driving time of truckers → higher turnover rate



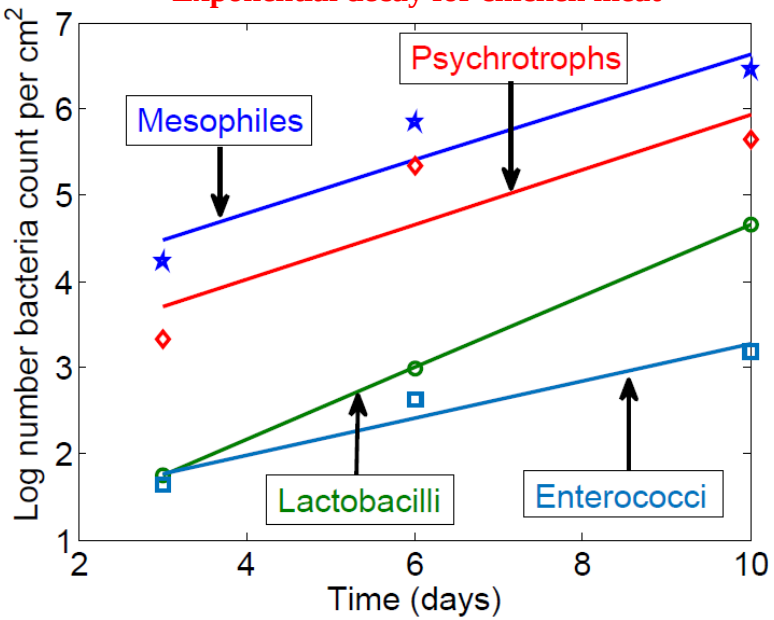
Food Freshness

- Fresh food deteriorate in quality over time
  - Governed by complex biochemical processes that depend on the food type, initial quality, temperature, humidity, vibrations, bacterial level, and bruises during storage/transportation
  - Fruits or vegetables generally follow zero-order degradation or linear decay
  - Meat or fish follow first-order degradation of exponential decay

Linear decay for vegetables

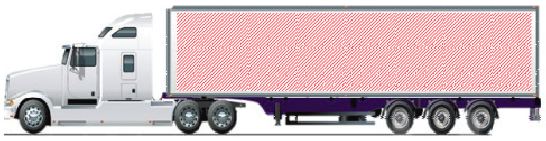


Exponential decay for chicken meat



Transportation Efficiency

- Transportation efficiency already pretty low in logistics, worse with local distribution
  - Small quantities at each location
  - Varying quality and quantity
  - Sharing of space between multiple products with differing perishability is challenging



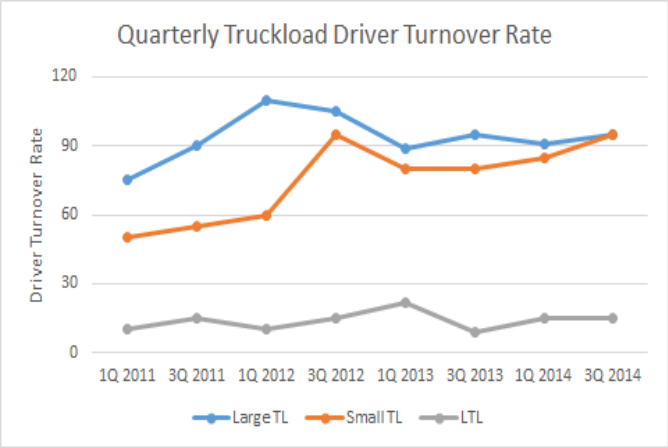
US Truck Transportation

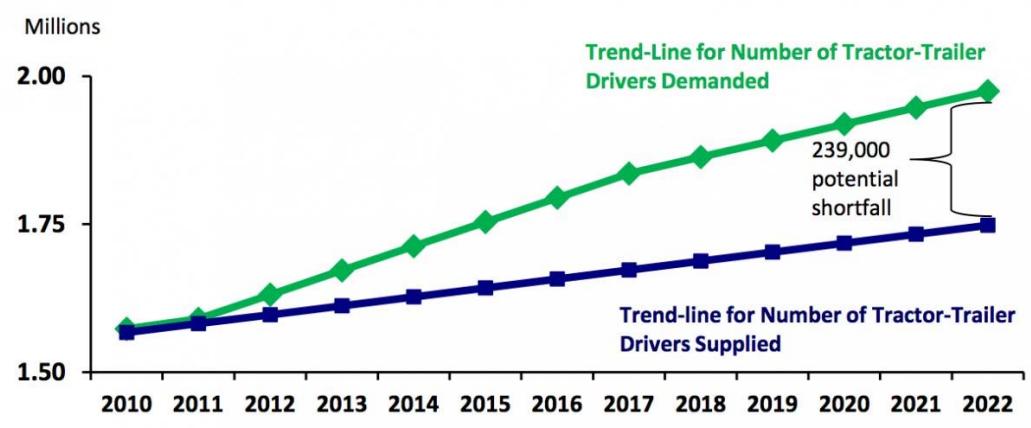
15-25% OF MILES DRIVEN ARE EMPTY

NON-EMPTY MILES ARE 36% UNDERUTILIZED

Long Driving Time: Higher turnover rate

- **Social impact**
  - Long driving time of the truck drivers → long stay away time from home for days and weeks → higher turnover rate → driver shortage
  - Truckload industry as a whole replaced the equivalent of 95% of their entire workforce of drivers by the end of 2014
  - The truck driver shortage is expected to surge to 239,000 by 2022





*http://www.conceptservicesltd.com/how-industry-leaders-are-combating-the-truck-driver-shortage/

*http://www.businessinsider.com/american-truck-drivers-are-getting-squeezed-out-of-their-profession-2014-8

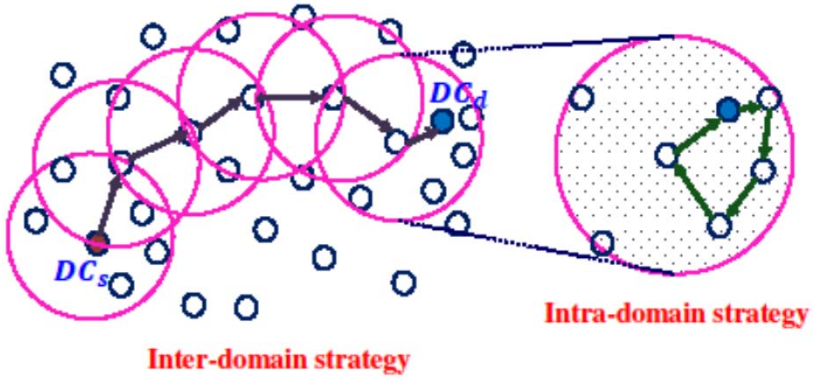
Our Approach

- **Shared architecture**
  - The truck vendors carry the packages in between different distribution centers → truck capacity is shared → improves efficiency
- **Dividing longer trips into smaller hop**
  - The long truck journey is divided into smaller trips → reduces the truckers away home time
- **Integrating the freshness metric in package delivery**
  - Makes the problem more challenging
  - Tradeoff in between fresh delivery and transportation efficiency

$F^2\pi$: Package Forwarding Strategy

Zone Base Forwarding Strategy

- **Solution**
  - Divide the long journey of a truck drivers among multiple drivers
  - Each truck runs within smaller zones → reduces truckers away home time
  - Truck load-unload packages of multiple DCs in his journey → improves the transportation efficiency
  - Inter-domain and intra-domain forwarding strategies



Intra-domain Forwarding Strategy

- **Factor1:** Given the orders what is the best truck routing to maximize the overall transportation efficiency
  - Function: Total amount delivered per unit time.
  - Can be run periodically to decide schedules dynamically

$$\text{Maximize} \quad \frac{\sum_i \sum_j \sum_t \sum_\ell d_{ij}^{t\ell}}{\sum_i \sum_j \sum_\ell x_{ij}^{\ell}.T_{ij}}$$

Efficiency factor

- **Factor2:** Maximize the overall delivery quality
  - Function: Delivery quality*total amount delivered

$$\text{Maximize} \quad \sum_j \sum_t \sum_\ell \sum_i \left(\mathbb{Q}_{ij}^t - k^t B_j^\ell\right) d_{ji}^{t\ell}$$

Quality factor

$d_{ij}^{t\ell} \triangleq$ Amount of type t unloaded at $\boldsymbol{DC_i}$ from $\boldsymbol{DC_j}$ at the ℓ-th transit-segment

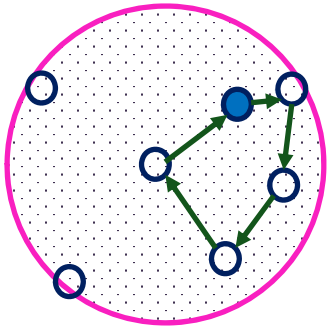
$B_j^\ell \triangleq$ Time when the truck delivers at $\boldsymbol{DC_j}$ in the ℓ-th transit-segment

$T_{ij} \triangleq$ Time of travel from $\boldsymbol{DP_i}$ to $\boldsymbol{DP_j}$

Intra-domain Forwarding Strategy

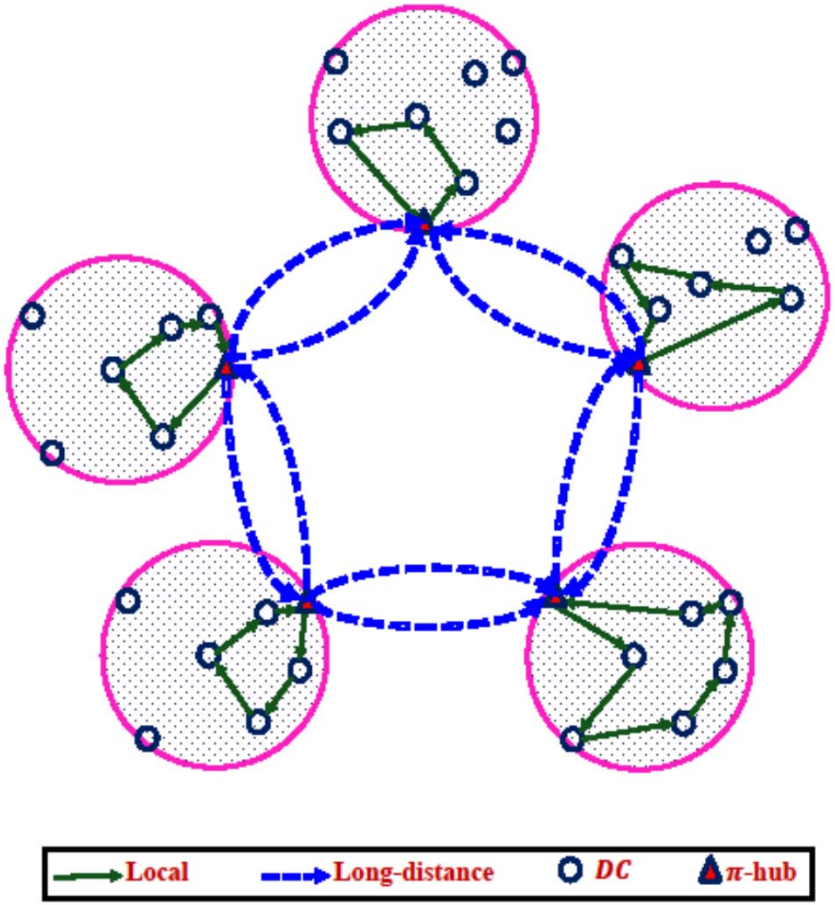
- **Constraint 1:** The delivery quality is above certain threshold

- **Constraint 2:** Truck needs to return to its starting point within its maximum limit



Local and Long-distance logistics

- These DCs can be π-transit, π-switch, π-bridge, π-gateway, π-hub → depending on their role in the distribution logistics
- Integration if local and long-distance logistics
  - Local distribution → small trucks or trailers
  - Long-distance distribution → large trucks (18 wheelers)

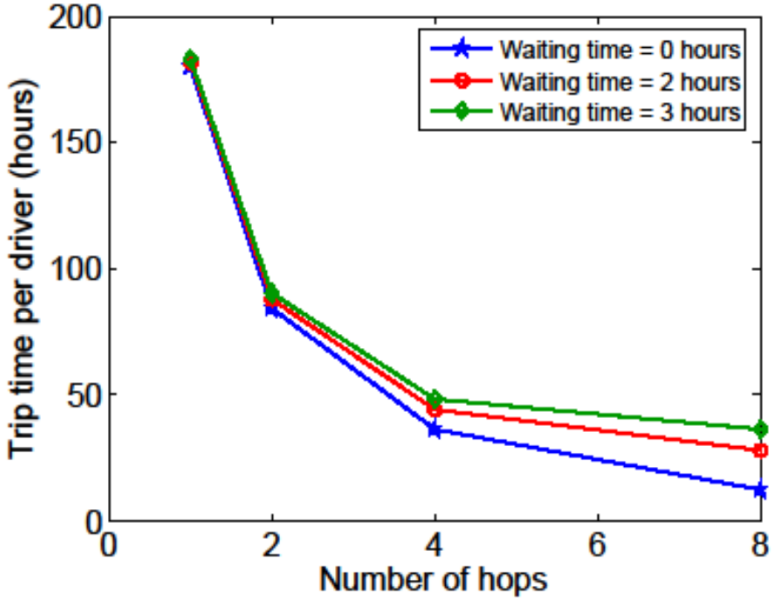


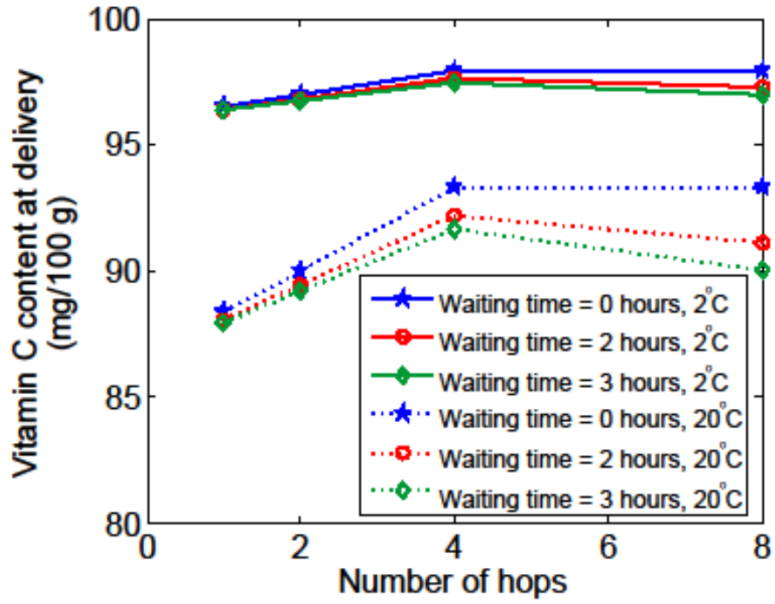
Performance Evaluation

Effect of smaller hops

- A truck carries broccolis with Vitamin C content of 99.9 mg/100 g initially
- Two types of environments → chilled environment (2^0 C), warmer environment (20^0 C)
- At 2^0 C, k = 0.0408 mg/100 g in an hour, at 20^0 C, k = 0.1375 mg/100 g in an hour
- A truck needs to deliver packages to a DC that requires 48 hours of driving time → driver drives 12 hours continuously, takes rest for 12 hours

By introducing 8 hops → trip time/driver is reduced by ~93%, freshness improves by ~5%





Intra-domain forwarding

- Two types of vegetables: raspberries and broccolis
  - At 2^0 C → deterioration rates of 0.0229 mg/100 g and 0.0408 mg/100 g per hour respectively
  - Initial Vitamin C content is assumed to be 27 and 99.9 mg/100 g
- Truck capacity limit of 100 packages
- T_{min} is assumed to be 6 units

Order matrix

	A	B	C	D	E
A	-	*X*	*X*	*X*	*X*
B	-	-	*X*	-	-
C	*X*	-	-	-	*X*
D	*X*	-	-	-	*X*
E	*X*	-	*X*	*X*	-

Time matrix (Hours)

	A	B	C	D	E
A	-	2	3	3	3
B	2	-	2	3	3
C	3	2	-	1	1.5
D	3	3	1	-	1
E	3	3	1.5	1	-

Intra-domain forwarding

- Two types of vegetables: raspberries and broccolis
  - At 2^0 C → deterioration rates of 0.0229 mg/100 g and 0.0408 mg/100 g per hour respectively
  - Initial Vitamin C content is assumed to be 27 and 99.9 mg/100 g
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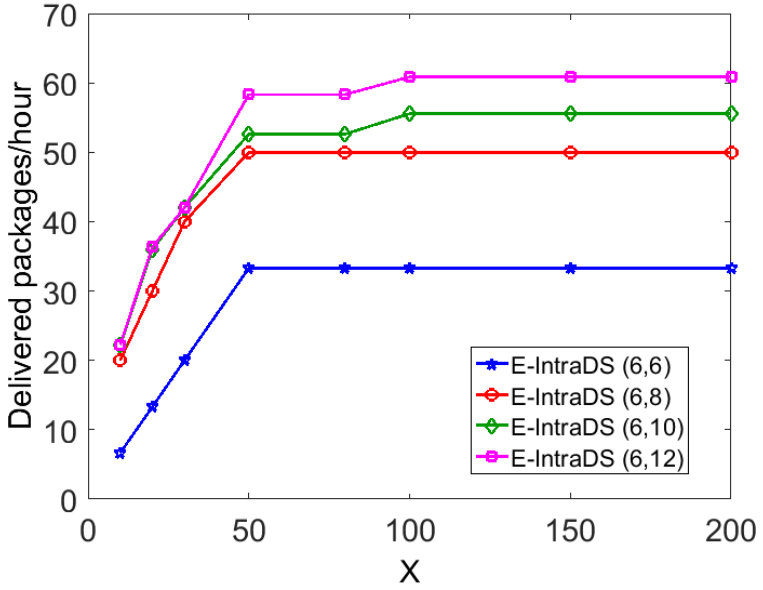
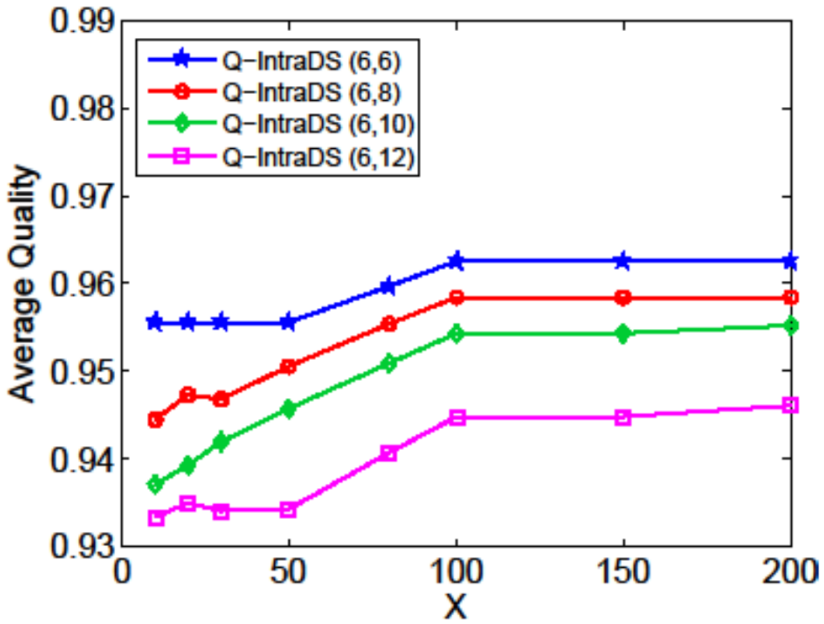
Improving efficiency results in reduced delivery quality and vice versa





Conclusions

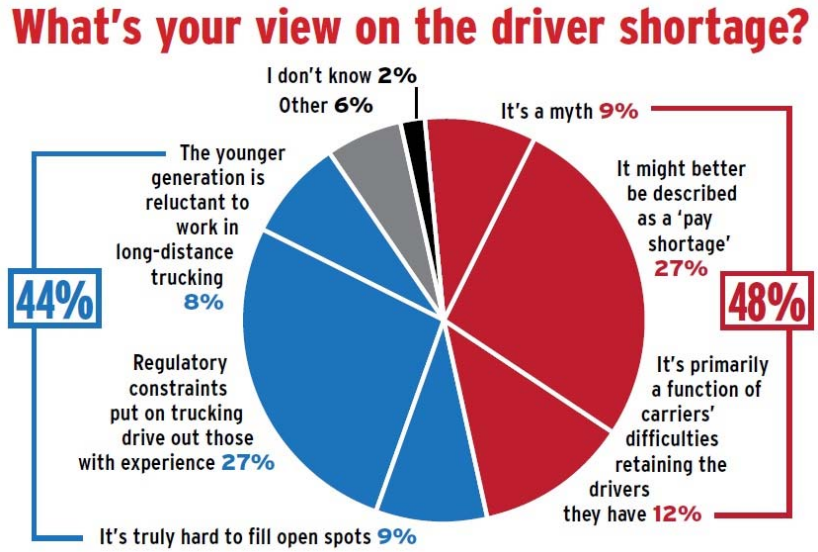
- We explore $F^2\pi$ architecture
  - with the notion of **collaborative truck scheduling and space sharing**
  - Reduce trucker's away home time, improve the transportation efficiency and maintain fresh delivery of packages especially important for perishable food packages
- Key findings of the proposed architecture
  - Improves drivers away home time by ~93%
  - Improves delivery quality by ~5% by dividing the long driving distance into smaller hops
  - Tradeoff between transportation efficiency and freshness
- The mechanism can complement current Physical Internet initiatives with a vision of worker-friendly and cooperative fresh food logistics and transportation

THANK YOU

QUESTIONS???

Long Driving Time: Higher turnover rate

- **Social impact**
  - Long driving time of the truck drivers → long stay away time from home for days and weeks → higher turnover rate → driver shortage
  - Truckload industry as a whole replaced the equivalent of 95% of their entire workforce of drivers by the end of 2014
  - The truck driver shortage is expected to surge to 239,000 by 2022



*http://www.overdriveonline.com/driver-shortage-readers-weigh-in/

Product Mixing

- First case:
  - Maximize $\sum_j \sum_t \sum_\ell \sum_i \left(\mathbb{Q}_{ij}^t - k^t B_j^\ell\right) d_{ji}^{t\ell}$
  - Broccoli's gets more priority because of less spoilage
- Second case:
  - Maximize $\sum_j \sum_t \sum_\ell \sum_i \left\{ \alpha \left(\mathbb{Q}_{ij}^t - k^t B_j^\ell\right) d_{ji}^{t\ell} + (1-\alpha).\frac{d_{ji}^{t\ell}}{\left(\mathbb{Q}_{ij}^t - k^t B_j^\ell - \Im\right)} \right\}$
  - Raspberries gets more priority → packages close to spoilage are transported first