A Motivating Example for Smart Data and Smart Services from China

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Abstract. An example from real industry to motivate the smart data, and smart services R&D, in pursuit of smart decision in IoT-aware business process management that actively takes advantage of change.

1 Background

Connecting the interior with the coast, the Yangtze river is playing an increasingly crucial role in promoting the river valley's economic growth and has become a vital link for international shipping to the inland provinces in China. According to the wikipedia[1], the Yangtze river is one of the world's busiest waterways. Traffic includes commercial traffic transporting bulk goods such as coal as well as manufactured goods and passengers.

On this busy transportation artery for China, the supply-chain management for ship spare parts (SSP) has been a major problem exercising the minds of all stakeholders of shipping companies and relevant enterprises. Normally, as illustrated by Fig. 1, a *vessel* fixes some faults, then applies for spare parts, and anxiously await replenishment while keeping its voyage. The shipping management company (the *manager*) validates the application and conducts an ordering business process to a *supplier*. Then, the supplier prepares the spare parts and assigns a *wagon* to deliver spare prats to the agent of the port based on requirement before the vessel docks. Traditionally, the destination of spare parts can only be delivered to some ports statically defined as the order placed (the message across the *manager* and the *supplier*). Occasionally, the *vessel* might ask to adjust the place or time of delivery via off-lined facilities, e.g. mobile phone, since it cannot be confirmed until the *vessel* anchored near a port.

However, there are always some uncertainties that either the spare parts would arrive too much earlier than the vessel (*with high expense for warehousing*), or worse they would miss the meeting point with the vessel (*with great hidden danger threatening future voyage*). Because the docking time is variably depends on the loading/unloading process of other vessels, if there is no vacancy of the port, the following vessels have to anchor and wait. Based on experience, 70%-80% bulk cargo carriers would be delayed on docking time, and the delay

[1] Yangtze. https://en.wikipedia.org/wiki/Yangtze

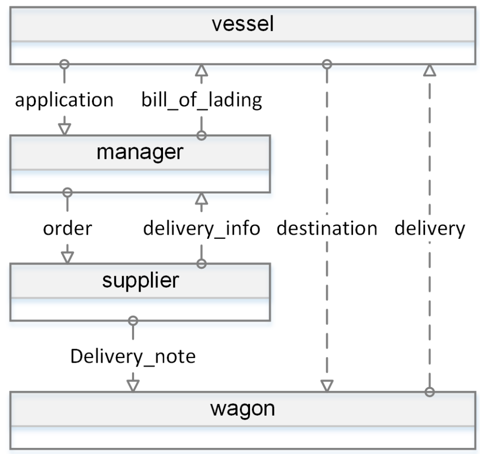

Fig. 1. A typical collaboration among processes in the supply-chain management for the ship spare parts scenario

period could be from several days to a few weeks. On the other hand, sometimes there left very short time slots for a vessel to dock. Further, there are some constraints on the erecting equipment at the port, so over-weighed spare parts cannot be lifted properly but have to move to the next available port. All these uncertainties lead to current approaches, e.g. static determination of delivery place and time, or off-line communication, are becoming more and more unsuitable.

Besides the above constraints on timing and erecting capabilities, the key fact is the cost. There are stocking fees for the agent, shipping charges for the supplier, or the extra docking fees for the vessel. Each of them wants to lower the costs, so the agent prefers to receive the spare parts the later the better, but the supplier prefers to choose economical shipping method by delivering the spare parts as early as better, while for the vessels, they can never accept any miss of the spare parts due to the highly expensive docking fees.

In general, it is very important to reach balance among the cost, the timing and the erecting capabilities in supply-chain management. It results in a collaborative business process problem in the context of moving objects. In the case above, the point is the Spatiotemporal negotiation between the *vessel* and the *wagon* as illustrated by Fig. 1.

2 Motivation

Given such uncertainties, how to engage business while maintaining comprehensive constraints on it becomes a challenge. Leveraged by IoT technology, we ought to take advantage of them actively, rather than passively succumbing to them.

As illustrated by Fig. 3, a *Vessel* on its voyage from Wuhan to Shanghai along the Yangtze river. On leaving Wuhan, sailors apply for spare parts to the *Manager* while keeps sailing. The *Manager* in Hefei starts a ordering processes

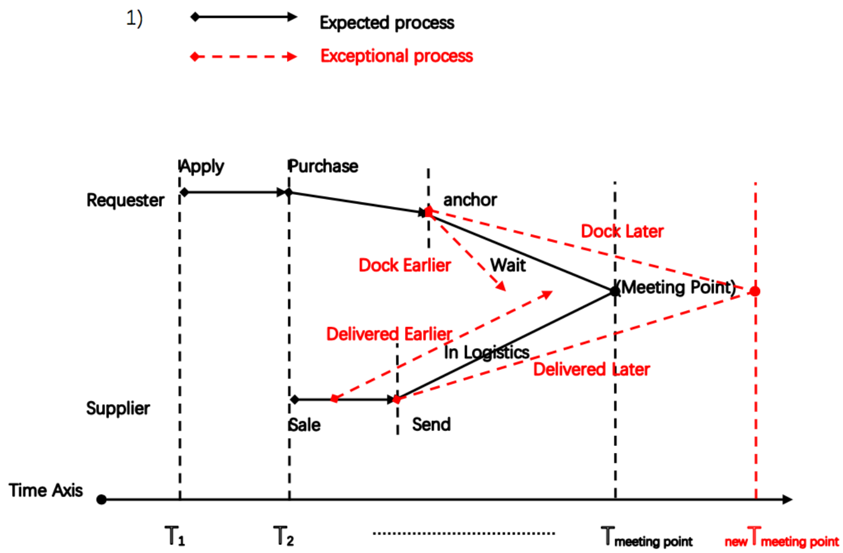

Fig. 2. An smart decision (proper meeting point) is expected in considering of processes both in logical world and physical world.

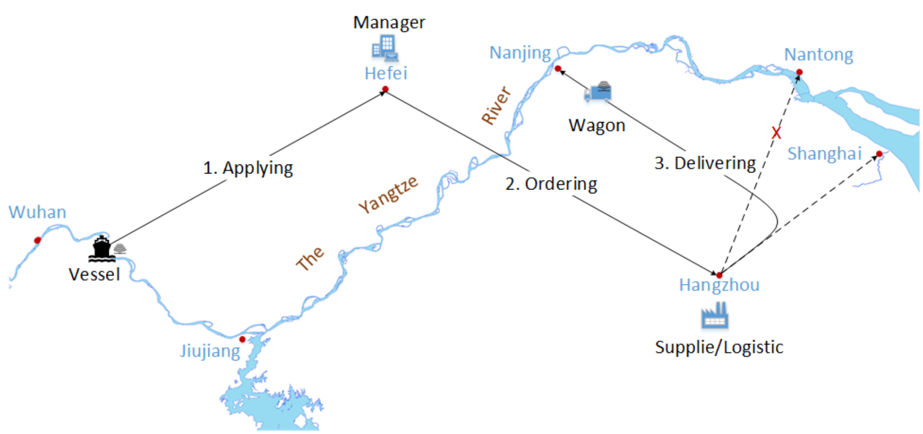

Fig. 3. An ideal scenario where the delivering of spare parts can be adjusted by using timely information of the vessel and the wagon

with the *Supplier* in Hangzhou. According to the shipping plan, ordinary experiences, and speed of the *Vessel*, there are only two possible ports on the route can dock, i.e. Nantong, and Shanghai, (the two dash lines from Hangzhou) once the order is settled. If we know that the spare parts this time cannot be lifted properly at Nantong, the resulted destination can only be Shanghai for delivery. Yet if we can get timely information from both the *Vessel* and the wagon in some way, say, the *Vessel* is now anchoring in Nanjing, and the time to dock is long enough for the wagon to reach Nanjing, then the wagon can change direction to there immediately (the solid line '3.Delivering'), so the risk in the future is reduced.

We can identify some issues in order to reach above expectation.

- proper process modeling approaches that can be guided by some attributes (e.g. too over-weighted to lift);
- proper modeling approaches that can characterize both business processes (e.g. the ordering) and dynamic physical processes (e.g. the voyage of the vessel and the movement of the wagon);
- smooth collaboration among above all kinds of processes specific to instances (e.g. negation between the *Vessel* and the *Supplier* at any moment.
- a new broker that can coordinate two parties with different domain knowledge.

We believe that the above-mentioned situation will be significantly improved if an IoT-enabled vertical integration could be set up, horizontal collaboration could be established based on data-driven process models, and constraints and fail-over could be easily controlled.

3 Some Earlier Results

To validate our idea, we have developed a prototype L2L, and asked H-goal[2], one innovative solution provider for shipping, to apply L2L to the supply-chain management in shipping industry of China.

Our earlier case study is around the SSP problem on shipping along the Yangtze river. We focus on the golden watercourse because of its significance in Chinese economy development. According to the report from the Yichai Global[3], the Yangtze River Economic Zone (YREZ) made up 43.1% of China?s USD 11-Trillion GDP last year. The Yangtze river is the busy transportation artery for China, but as pointed out before, the SSP problem has been troubling stakeholders around the bulk cargo shipping industry for a long time.

3.1 Goal

For the SSP problem, we want to validate if our approach could make agile decision to deliver spare parts against any change events. More specifically, for all autonomous operated participants, the vessel, the manager, the supplier, and the wagon, the rendezvous port can be determined dynamically in cases of

- vessel's delay in docking, and/or departure earlier/delayed
- the traffic condition on the way the wagon to deliver the parts
- the uncertainty in negotiation between the manager and the supplier

Our another objective is to analyze the economical benefits of applying the L2L approach against current manual style.

[2] www.h-goal.com
[3] https://www.yicaiglobal.com/

3.2 Experiment Settings

To make the SSP problem controllable, we study the case that there is only one vessel and one wagon in our case study. Of course, there would be more interesting issues if we deal with fleet. For example, there would be priority in replenishment, or delivery in the batch. These issues will be studied in the future.

All participants in the SSP problem, i.e. the vessel, the manager, the supplier, and the logistics in Fig. 1, are modeled as processes and deployed in activiti version 6.0. The IoT facility is implemented as IoT services. All services are locally deployed but data are either from real cases[4] for simulating vessel's voyage or from the 3rd party application[5] for simulating the traffic condition. The road traffic conditions are randomly set segment by segment as one of normal, slow or jam, which affects the speed of wagon as 1, 1/2, and 1/4, respectively.

3.3 Experiment Results

Seven typical scenarios are validated.
Normal delivery based on policies. The wagon delivers spare parts to the vessel at the rendezvous port successfully, either no any changes happened or the wagon reaches the port in time. In this case, L2L also has some advantages because of the introduction of dynamics in process modeling and coordinators, which can determine the rendezvous port based on moving objects.
Change rendezvous port to rest candidate ports due to bad traffic conditions. The wagon is on the way to the rendezvous port. Suddenly, the traffic condition ahead turns to be bad, e.g. traffic jam, it reckons that in no case at present circumstance can it reach the rendezvous port in time. It informs the coordinator VWC and the VWC can determine the next rendezvous port from candidate ones coordinating pre-configured policies. Then both the vessel and the wagon will target the new one as the coordinator indicates. It is one of the most representative cases leveraged by using IoT and coordinators. In traditional manual approaches, the delivery opportunity will be missed due to uncertain communication between the vessel and the wagon.
Success in delivering parts earlier when the vessel is delayed. The vessel is reaching a port but the rendezvous port is far ahead while the wagon is on the way to it. Suddenly, the vessel is informed to be delayed to dock because of no vacancy of the port. The wagon captures the information via the coordinator VWC, and calculated that it can reach the current port the vessel is reaching before its departure, it re-plans the rendezvous port as current one, and turn to it immediately. Finally, the wagon reaches the new rendezvous port before the vessel leaves. It is another representative cases leveraged by using IoT and coordinators. In traditional manual approaches, the delivery cannot be scheduled ahead because of not instant event perception and reaction agilely.

[4] http://www.chinaports.com/
[5] http://lbs.amap.com/

Change rendezvous port dynamically. This is the combination of above two cases. The rendezvous port was rescheduled to the rest one but then is being rescheduled back to the one precedent dynamically. This rescheduling could occurred several times, depending on the traffic conditions and/or docking information. It is the most vivid situation to demonstrate the benefits in agile decision-making leveraged by L2L approach.
Success in delivering parts at last candidate port when the vessel is postponed. The vessel is docking at the last candidate port while the wagon is on the way to it. According to the traffic condition ahead, the wagon cannot reach the rendezvous port before the departure of the vessel. Suddenly, the vessel is allowed to postpone for certain time longer (might due to the delay in docking). The wagon is informed by the coordinator VWC, and it finally reach the rendezvous port in time. It is yet another representative case leveraged by using IoT and coordinators. In traditional manual approaches, the delivery has to be missed because of the shortage of instant event perception and response.
Missing due to the departure from port ahead of schedule. This happens at the last candidate port. As long as the wagon is still on the way to the rendezvous port, it misses the delivery due to the vessel is forced to leave the port ahead of schedule. In this case, the wagon could be stopped immediately or assigned to another customer as a compensation to the missing. The L2L approach has potential superiority over traditional manual approach where no signal can be captured by the wagon.
Missing due to long negotiation between the manger and the supplier. Even the application for parts replenishment from a vessel is approved by a manager properly, it still misses the delivery due to the endless negotiation between the manger and a supplier, which results in no time for a wagon to catch the vessel at its last candidate port. In this case, neither the L2L nor manual approaches can provide valuable solution, as we expected.

One of the screenshot taken from above case studies is shown in Fig. 4. A video to reflect above scenarios of the SSP problem and technical effects gained by applying the L2L approach can be downloaded on the homepage of H-goal homepage.

3.4 Economical Benefits Analysis

Economical benefits in the SSP problem come from smart decision-making which deliver spare parts to the vessel in voyaging as early as possible in cases of all kinds of change. Hence, the value of L2L to the SSP problem can be evaluated in dimensions of efficiency of decision, the cost of decision-making.

For comparative purpose, we make some assumptions below

- all participants in the SSP problem are willing to collaborate in traditional approaches;
- each decision cost model is aimed at the same kind of decision;
- the decision in the unit time is independent and conforms to the positive proportional function.

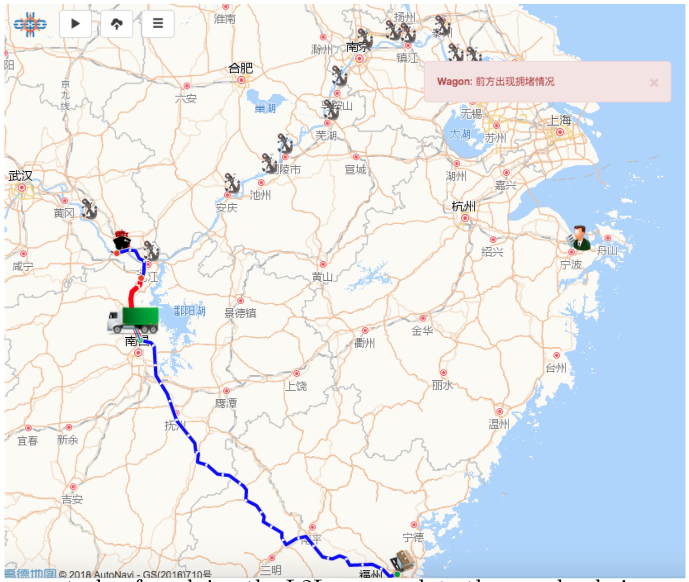

Fig. 4. An case study of applying the L2L approach to the supply-chain management in shipping industry of China. By taking the advantage of L2L's adaptability and agility, spare parts can be replenished in a most efficient way.

Traditional approach (*as-is* in Fig. **??**) intermittently obtains the message of change, which contributes to high cost of communication and decision-making. Contrast to it, in the L2L approach (*to-be* in Fig. **??**), all participants that are modeled as processes can continuously capture instant change events (the delay information or traffic conditions) through IoT devices, can handle events and make decision immediately, which promotes the collaboration considerably. As a result, the L2L approach can deal with change quickly. Further, it can take advantage these changes to produce better decision, e.g. guiding the wagon to earlier ports if the vessel was delayed.

Let's analyze economical benefits in term of decision cost as Fig. 5. We formulate the total cost of decision as

$$T_n(x) = V_n x + F_n$$

where,

- n denotes the decision type
- x the average number of decision demands per unit time
- $T_n(x)$ the total cost per unit time, V_n variable cost (including opportunity cost and labor cost) for each decision per unit time, and
- F_n The fixed cost of policy-configuration (including opportunity cost and labor cost) per unit time

There are three types of decision, say

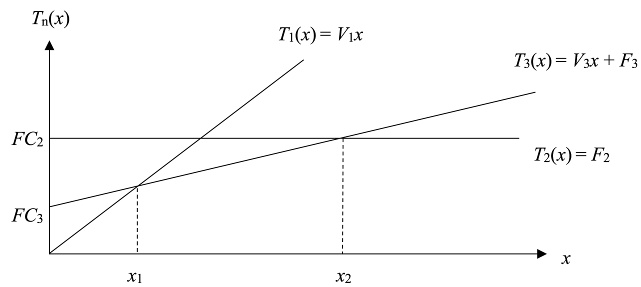

Fig. 5. Smarter decisions made by L2L (to-be in Fig. **??**) result in lower total cost comparing to traditional manual negotiation (as-is in Fig. **??**). The critical factor is the agile reaction to changes.

1. *Manual.* $T_1(x) = V_1x$. Get the change information intermittently by human communication and make a decision. At this point, there is no need to configure policies in advance, and hence there is no fixed policy configuration cost, i.e., $F_1 = 0$;
2. *Automatic.*$T_2(x) = F_2$. Continuously capture the change events through IoT technology and allow the coordinator to automatically adjust the decision according to pre-configured policies. At this time, each decision is done independently by the coordinator, the opportunity cost or the labor cost can become negligible, that is, $V_2 = 0$;
3. *Hybrid.* $T_3(x) = V_3x + F_3$.

Generally, if both the traditional approach and the L2L can achieve the same decision efficiency, the indirect economic benefits are the same.

In order to maintain a stable decision-making efficiency, traditional approach has to invest more resources (e.g. labors) as the average number of decision requests X_i increases per unit time, so the total cost of decision-making per unit time will accordingly increased. However, in practice, there are cases that no matter how much of investment, it is still impossible for manual approach to achieve the efficiency of L2L in decision making, the missing decision opportunities will definitely hurts potential economic benefits, which can be regarded as part of variable cost of every decision per unit time.

The fixed cost F of policy configuration distributed to the unit time δt can be calculated according to the total fixed cost TF of certain policy and the average probability p of the decision demand for responding to events during the whole life cycle T, i.e. $F = (TF \times \delta T)/(T \times p)$. For example, a set of policies that can be used for one year (365 days), the unit time is 1 days, so when the probability of decision demand is 100%, the cost of the policy configuration can can be distributed to 365 days, i.e. $(365 \times 100\%)$. Similarly, if the probability of occurrence is 20%, the cost of the entire policy configuration can be set as 73, i.e. $(365 \times 20\%)$.

To this end, we should aim at reducing the total cost of decision-making within a unit time when we choose a proper decision type. More specifically, referring to Fig.5, when a participant's average number of decision demand per unit time

- is less than X_1, it tends to make decisions mainly by human intervention;
- is greater than X_1 but less than X_2, it will adopt L2L policies, and partially assisted by some human interventions;
- is greater than X_2, it should definitely adopt L2L and rely on coordinators reacting to asynchronous events.

In summary, the L2L approach is most suitable for following cases:1) dense demands for decision making, i.e. a higher X_i; and/or 2) frequent demands for decision making, i.e. lower F_i; and/or 3) the fixed cost of policy configuration remains controllable. i.e. lower F_2 and F_3.

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