Discovering the EIS Architecture that Supports Hub-and-Spoke Freight Transportation Networks Operating in a Cross Dock Mode

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Abstract: We propose a line of research for road freight logistics that may deliver novel enterprise information system (EIS) architectures, procedures, and novel ways of applying existing technology, with the direct objective of enabling and making more efficient a variation of an existing logistic scenario, which is presented to some extent in this position paper. We argue that the enabling and support of this setting via appropriately identified, tested, and practitioner-validated EIS functions may have the effect of increasing the load factors in palletized road freight, as well as allowing mass Just-in-time (JIT) trans-shipment from small scale suppliers and delivery to small scale end-customers.

1 INTRODUCTION

Recent studies (Marcucci and Puckett, 2012) show that the average truck load factor for palletized transport in Germany is 51%. Other national level data estimates for EU countries give values that are even lower than 50%. In two extreme interpretations, these numbers suggest that either most trucks travel half empty all the time, either that they travel empty half of the transportation time (e.g. one leg of their transportation journey). It is hard to believe that these numbers are still so low, in the light of the fact that dedicated enterprise information systems (EIS), which contain functionality for supporting the customer management, operations, and analytics of the palletized road freight industry have been massively deployed in recent decades.

Moreover, "cross-fertilizing" research activities of vendors, practitioners, and academics led to the development, standardization, and continuous enhancement of various transaction and decision support systems like highly complex Warehouse Management Systems, Fleet Management Systems, Yard Management Systems, Tracking and Tracing Systems, as well as web based communication and coordination systems. All these make use of versatile, affordable, and embedded technologies like board computers, GPS, RFID, wireless internet, etc. Today, academic research is focused mostly on various optimization problems faced when applying novel kinds of logistic scenarios, leading to a plethora of algorithms for resource allocation, operations scheduling, route planning, network and facility design, etc. The innovative professionals in practice contributed most to the improvement of these logistic scenarios. However, there are still gaps of understanding between these two communities.

Our position is that academics doing research in logistic process supporting ICT should be encouraged, facilitated, and be able to better communicate their own ideas directly to practitioners. A potential way is to transform the manner in which case studies – used to gather empirical knowledge directly from practice – are executed. Academics should have illustrative tools which can be easily set and parameterized to reflect the situation encountered in practice, and allow practitioners and academics to cooperate for improving scenarios and finding new ones.

This paper proposes such a way of cooperation for potential research. We present first two related logistic scenarios in LTL road freight that have been investigated via a multi-year multiple-case study – involving 13 large cases and a significant number of smaller cases. The analysis of the results of these studies revealed that in the execution of a variant of the second scenario, there are still unanswered questions about the functions necessary in the supporting EIS architecture. That makes the effective execution of this scenario variant difficult.

2 BACKGROUND

Increasingly, road-freight transportation companies are confronted with shipments comprising smaller volumes of freight which require more frequent transportation with reduced lead times. These Less-than Truck Load (LTL) shipments are volumes of freight not large enough to justify dedicating an entire truck, but are too large to transport by means of a parcel delivery service. To realize economies in transportation costs, these shipments are typically *consolidated* with many other smaller-sized shipments in order to transport them as full truck loads. For example, in a *cross dock*, the consolidation is performed while aiming for minimum dwell-time between receiving and shipping the freight (Boysen and Fliedner, 2010).

One of the main drivers that made cross docking increasingly popular and necessary was the large penetration of the Just-In-Time (JIT) strategy in various manufacturing industries. Logistic management quickly adopted JIT in transportation and distribution, foreseeing correctly the desire to achieve large reductions in inventories throughout the supply chain. Already at the end of the last century, a vast percentage of the freight distributed by the top mass merchandisers (such as Walmart and Kmart) have been consolidated at cross docks (Napolitano, 2000). However, smaller companies are only now starting to make the move towards JIT-like delivery in their supply chains.

Cross docks appear in various sizes and configurations, and there is still some debate about the "exact" definition of a cross dock (Vogt, 2010). To provide our interpretation of cross docking, we propose three inter-related features characterizing any cross dock, which remained unchanged since the original definition given in (Napolitano, 2000):

(i) *Every effort* at a cross dock is made to facilitate the flow of freight from the inbound vehicles to the outbound vehicles in the minimum amount of time possible.

(ii) There is no explicit inventory kept. The freight is either moved directly from the inbound vehicle to the outbound vehicle, or allowed a short stay (named "staging"). Including a potential period of staging, a shipment typically stays less than a day. Moreover, no fee is charged by the transhipment facility for the staging of a shipment.

(iii) In a transportation networks with a transhipment facility, the information flow is preceding the physical flow of shipments. The supply chain actors give considerable attention to the synchronization of inbound to outbound shipments.

This is achieved by means of externally synchronized schedules, which aim to reduce the trans-shipment time and resource utilization at the facility, while reducing handling and transportation lead times in the network as a whole.

We consider that only the first feature (i) is fundamental for a cross-dock. Other logistic settings may have (ii) and (iii), but if they do not present (i), we, and many other researchers, do not consider them a real cross docking setting, albeit (i) is practically impossible to be realized without (iii). In the following sub-sections, we present two logistic scenarios with trans-shipment – one with that has the cross dock fundamental feature (i), one that does not have it, but clearly has (ii) and to some extent (iii). After these two, we present a variation of the second scenario that has elements of (i) and (ii), but it is still lacking a proper understanding of how (iii) can be fully realized form an EIS point of view.

2.1 Observed EIS Functionality for Single-direction JIT Consolidation

This scenario refers to moving a shipment item from a supplier and delivering it its consumer with little material handling in between, only by passing it fast through a cross dock – without the intermediate steps of disposition, storage and order fulfillment done in warehouses. The shipment is arriving in a truck/trailer that contains multiple LTL shipments to various consumers. These resulted from the same supplier or an optimized "milk-run" from neighboring suppliers. Immediately, the shipment is moved to an outbound truck/trailer to consolidate a full truckload (TL) for a consumer or consumers that are easy to deliver to in one run – because they are geographically close for example. At the moment the full TL objective is achieved, the outbound truck/trailer leaves immediately. In some instances, the pallet does not touch the floor of the facility, being moved directly from trailer to trailer, and in other instances very short staging may be necessary. The speed of this kind of material flow allows precise JIT delivery at the consumer's site (Erera et al., 2013).

This scenario is implemented for certain products in manufacturing supply chains, mostly for perishable or promotional goods, but also for products for which the demand and supply is highly predictable. There are a series of ICT requirements on the accompanying information flow and also on the necessary resource allocation and planning interaction (Larbi et al., 2011). Today, the procedures and technologies used to support the

monitoring, coordination and control of such a logistic process are well established (Van Belle et. al, 2012).

Large distribution and retail organizations, supply chains like the ones in the automotive industry, and also non-parcel transportation services (for palletized freight) are using variations of this scenario, and ample practice-based experience with the ICT related issues exists. Also, there is substantial empirical knowledge about the used in practice EIS architectures and models. This empirical information was mostly collected and analyzed by academics, but also by vendors and consultants.

From a functional point of view, derived directly from critical requirements of operating as a cross dock, the focus is on four *main* functions for an EIS that covers the whole network:

a. Support for synchronization of trailer arrivals and departures
b. Support for synchronization of the internal operations with the schedules of the trailers
c. Support for dynamic door allocation
d. Support for staging decisions

The first functionality is required because there are strong dependencies between the load of various inbound and outbound trucks (Liao et al., 2013). This is easily achieved if the overall supply chain synchronization is already in place (that is, the supplier's and consumer schedules are already aligned, which is natural in an JIT or/and lean manufacturing setting, see Luo and Noble, 2012).

The second and the third functionalities are realized by a mixture of tracking, identification technology, and transaction processing, having on top of these various dynamic resource allocation mechanisms (Liu and Takukawa, 2010). Dedicated optimization-driven components perform the fourth function.

What is interesting about the focus on these functions is that most of the practitioners interest and also the ICT academic research emphasize only the operational decisions "inside" the transshipment facility. What is happening "outside" is taken as given fact, and makes the rather strong assumption that the supply chain operation and the transportation schedules are already in synch. What it makes it work in practice is that the external structure of the overall transportation network in such a scenario is rather simple and the flow is viewed as single-directional through the cross dock facility.

2.2 Observed EIS Functionality for Hub-and-Spoke Consolidation

This scenario refers to moving a LTL shipment to a location named hub from a location named spoke - by an inbound hauler that plays a local logistic operations role in the spoke's area. The shipment order is made by a supplier who also pays upfront this hauler for the whole delivery to the target consumer. When the shipment is staged at the hub, or in some cases in advance, the hub operator hires immediately another hauler (operating in the area of the target consumer) to take the staged shipment from the hub and deliver it. When this outbound hauler has enough load at the hub or in hub's neighboring area to consolidate its truck trip, it sends a truck (typically loaded with shipments intended for the same hub or close to it) to bring the full LT in its area and finally delivers these shipments. Typically, the haulers that bring inbound shipments seek to take a full load back, from the hub or its surroundings, in order to keep load factors high.

The main feature of this scenario is its heterogeneity. The hub, in most cases focuses only on its own internal operation and rarely operates its own truck fleet. For the transportation from/to the hub it relies mostly on local haulers, and it may have different type of contracts with them – long, short-term, or ad-hoc, depending on their size and the variability of the flow they enact through the hub. The way the haulers operate on their side can be also very different. Some use their own smaller hub, transshipping from/to smaller trucks that do the local milk-runs to/from bigger trucks that do the spoke-hub route, and some do directly the milk-runs. From a dynamic information flow point of view, the haulers need to know what is present (or will be in the near future) at the hub, which makes their own TL consolidation, truck scheduling, and truck routing tasks easier. This information function requested by the hub is called *manifestation*. It is possible to pre-manifest loads that are to arrive at the hub in the near future, and in some cases, haulers who have long term contracts with the hub do that, via an ICT infrastructure that is deployed or adapted for this purpose. However, our multiple case study reveals that albeit considered useful by various stakeholders, many found that the cost of this infrastructure does not justify the investment.

We have also observed that the logistic operators (hub owner, local haulers) implementing this scenario serve a completely different market than the ones in scenario 1, where the supply networks are typically required to support the JIT manufacturing

or distribution of a large organization in a supply chain. For scenario 2 networks, the size and industry sector of their clients providing and receiving the freight can be very diverse. Most of the customers of a scenario 2 network are small and medium-sized companies. The relatively fast (only a few days) by-road transfer through a country-, or continental region-size network allows these pairs of supplier-consumer to achieve an "almost JIT-like" performance of operating their supply chains.

On the other hand, it is still difficult to give to these end-customers a reliable prediction of the throughput time of a shipment – and hence, a precise (JIT-like) delivery time. This is due mostly to the heterogeneity and the operational loose coupling of the logistic companies involved. Their transport decisions are made autonomously and at different moments, and these are always dependent on other factors, like the variability of demand and supply of *other* end customers – which are not using the hub and spoke network. The dynamic decision of the hub to which outbound hauler to hire for a shipment, its availability, and its response also contribute to this overall lack of predictability. Moreover, the daily schedules and truck load distributions made by any pair of haulers are never coordinated to take into account the eventual dependencies between the inbound and outbound shipments they may share.

In an operating mode that allows that these inbound/outbound dependencies do not interfere with overall performance, which can be easily achieved when the whole daily flow is transshipped in one shift, the customers can be sure that that the throughput time is the predicted one (with the reserve that the inbound and outbound haulers have no technical problems). This time equals to the sum of the time from picking to staging at the hub, plus the staging and transshipment time, plus the hub to delivery time. Such an operating mode assumes that all trucks in a shift arrive before a "unload spike" moment, and *all* the flow volume of this shift is staged at the hub. Only after the loading of the outbound trucks – which all arrive in time at the hub yard – starts with a FCFS strategy for example. There will be a "load spike" moment, but there is enough slack in the transport and delivery schedules of the outbound haulers to deliver each pallet load in time.

The focus is on four *main* EIS functions that are necessary for the whole network operating under this scenario are:

  a. Support the manifest of existent and incoming flow at/to the hub
  b. Hub to hauler relations management
  c. Hauler to end-customer relations management
  d. Truck schedule, routing, and truck load optimization (locally executed by haulers)

Compared with the four main functions identified for scenario 1, these four function emphasize the focus on the "outside" of the transshipment facility. The first function is performed through a mix of identification, tracking, and web-portal technology that links the hub to the rest of the operators – only this function has a real-time input that comes from "inside" the hub, albeit it depends on what the "outside" manifests as load. The second function is achieved through classic CRM, and it covers the long-term management of the different types of contracts and agreements between the hub operator and the spoke area operators. The components that perform these two functions are typically owned by the hub operator. The third function is performed rather independently from the first two by a heterogeneous mix of components owned by the haulers. The same heterogeneity and distribution is observable in the physical realization – or even the lack – of the fourth function.

2.3 A Close to Capacity Operating Mode of Hub and Spoke Consolidation

The temporal dependencies between inbound arrivals and outbound departures become critical in two situations, which can appear together. First, the "unload spike" and the "load spike", due to a lack of enough slack in the transportation schedules – or other factors – can become too close to each other, and the effect is that the hub has less and less time to process the whole daily trans-shipment volume during a single shift. Second, the departure from a continuous hub flow operation towards a daily shift style may cause that the volume that accumulates at the height of the operational cycle is actually close or even higher than the physical capacity of the hub. This cycle height is positioned during "unload spike" and the "load spike". When these situations occur – and some of cases studied by us show that they happen more and more often – the hub starts to operate in an "extreme" mode that resembles the cross docking operation mode.

Indeed, hub and spoke operators who have been interviewed stated themselves that they do "cross docking" (Buijs et. al, 2012). However, in all of these cases, our independently made observation was that the fundamental feature of cross docking (i) is actually missing. Even if, for all means and purposes, a hub is not an inventory point any more,

and the information flow may precede the physical flow, that does not mean that the hub can be considered a cross-dock. The main EIS related reason for this inference was that we have found no functionality that was intended for the coordination of operations or the optimization at the level of the whole network – therefore a lack of the fundamental feature (i) presented in section 2.

The main position of this paper is that when the flow at the hub transshipment facility approaches near maximum capacity and/or the temporal dependencies prevent the fast (cross dock style) outbound move of the shipments, the main issue is the lack of those EIS functions that allow for coordination at the level of the whole network.

An EIS that would support to achieve the cross docking fundamental feature (i) in a hub-and-spoke network, would create in fact a JIT-enabling network. There is a potential market today for "real" JIT shipments between those SMEs which intensively use road freight hub-and-spoke 3PL operators for country and continental region wide supply chain operations (Kemény et. al, 2011). The perceived advantages of this operating mode for hubs are the following:

I.   Throughput times for pallet-based shipment from supplier to consumer can be reliably predicted, hauler delivery promises kept, and JIT levels in the supply chains can be achieved for a large number of SMEs.

II.   Prices for fast and reliable shipments can be reduced to the level of normal hub-and-spoke delivery – down from courier shipment price levels, and can be afforded all the time, by everybody, not only by a small "elite" or only in exceptional rare circumstances.

III.   3PL operators which will make the transition to this mass-scale JIT-enabling will become transportation network orchestrators and by doing this they open themselves to a lucrative business model and a new channel of revenue.

3   DISCUSSION

An observation made during the multiple-case study is that the realization of this interesting operating mode is effective only for a certain type of hub and spoke operations. For example, almost any 3PL operator who wants to extend its current logistic/warehouse processes with hauler network-based hub and spoke JIT consolidation flow, using its existing dock door procedures, will encounter serious difficulties. Here we enumerate some of the

often occurring features that would make the adoption of this mode practically impossible:

1. if the level of constraint interdependencies between the inbound and outbound flows is high and also difficult to predict.
2. if the variability of the timing of the "spike" of operations' tempo at the hub moments is high.
3. if the trucks are loaded or unloaded only through their backdoor, and the local constraints of ordering the pallets in the outbound trucks are strong.
4. if there is limited staging capacity and there are constraints on the internal trans-shipment resources (like forklifts).
5. if one of the main functions identified for the scenario 1 EIS are not present.

All these restricting features, and most importantly the lack of any EIS-level coupling between the "inside the facility" and the "outside of it", will make extremely difficult the attempt to achieve the synchronized (cross dock style) flow of pallets through these trans-shipment facilities.

3.1   What EIS Functionality is needed to enable the Cross Docking Mode

The first and most striking ICT infrastructure related observation made at the hub operators that encountered the close-to-capacity mode was the lack of interfaces between the various components of the network wide EIS – i.e. the loosely-coupled one covering the entire hub-and-spoke network. The second interesting observation, made repeatedly at different hub operators during the multiple-case study, is that planners from different operators continuously and pro-actively collaborate in order to facilitate the smooth trans-shipment of particular orders. However, due to the lack of dedicated interfaces, there was no effective support for this collaboration from the EIS, and as a result, the handling of the situation was human-work intensive, and the communication was exclusively done via POTL (plain old telephone line). Furthermore, the interaction was decidedly un-structured, albeit some patterns emerged when thoroughly investigated.

Based on this observation, our first intuition is to have an EIS function that *provides visibility* between various planning and scheduling components of the network wide EIS. In physical terms, this can be achieved by enacting intelligent interfaces between EIS components. These should be able to detect, filter and report changes in the schedules of others, and also be able to estimate the negative effects and eventual opportunities caused by these changes.

These interfaces should be designed in a way that triggers the planners in different organizations to act, interact, and decide for more efficient courses of action when necessary. Nevertheless, there are many difficult issues related to visibility, for example confidentiality – haulers may compete against each other in the same spoke zone – and all these have to be carefully analyzed before deploying such a function. Some current tracking components offer alarm and triggering features, but some operators used these parsimoniously, because it is very difficult to set the constraints in the system, and the excessive triggering may become more a hindrance than help for the planner (Meyer et al., 2012).

The second observation is that typical operation related tasks as load building, schedule computing and various resource allocations, are all made and optimized in a hub and spoke network only from a local ("greedy") perspective (Shakeri et al., 2012). This may lead to degraded network-wide performance indicators, and in the long term potential loses for all involved. The collaborative alignment of the plans and schedules, made with the purpose to achieve a win-win network wide outcome, would be possible only if the interfaces performing the "provide visibility" function are in place. However, these interfaces alone would not be sufficient to achieve schedule alignment.

Our second intuition is to have a function to *align intentions* between the various components that support planning and scheduling. The experience gained and the technology used in aligning supply chain partners can be of use here. For example, various auction based mechanisms and agent based systems (Fischer et. al, 1996), automated negotiation (Davidsson et al., 2011), and the technology of intelligent products (Meyer et. al 2009) can be applied for the implementation of the necessary components to perform this function. Of course, we are aware that the realization of such a function is not trivial (a list of these difficulties is presented in Mes et al., 2011), and we also know that the main issue revolves always around the establishment of an incentive mechanism that brings partners into collaborating for win-win situations. We believe that the discovery and testing of models for these incentive mechanisms will be one of the most difficult parts of the research. Also, each hub and spoke network may have different requirements and attitudes that makes the model unique for the network, and the generalization of these models may prove to be very difficult.

Beside these two strong intuitions above, other potential intuitions we have for the EIS functionality are: first, to *provide network wide optimization* (to enable look-ahead and potential performance evaluation); second, *provide pro-active, network wide, real-time, operational monitoring and control*. Related to this last function, our research group has already experimented with components performing this function, in one of the cases of the case study research (Meyer et al., 2012). Another interesting idea is to continuously gather network wide historical data and *provide analytics* (based for example on data mining and learning), to allow planners and decision makers to observe change over longer intervals of time and maybe discover in this way emerging and useful patterns of interaction that can be developed further to improve the alignment function.

Nevertheless, at this stage, we can say that these are only our educated intuitions for functionality. Only applied and active research can establish with certainty which functions are effective in enabling and improving hubs that will operate in the cross docking mode.

3.2 How to Identify, Test, and Validate the Functionality of a Hub and Spoke Supporting EIS

Both the market essentials and the technology in this field of research have been evolving and changing fast. To discover the currently needed functions and evaluate their effectiveness quickly, the research must involve from the start a certain number of cooperating practitioners from the operators. Because it is extremely difficult and disruptive for the operators to run pilots embedding experimental prototypes – as we have observed during our active research attempts – another approach for this cooperative research is necessary. Our proposal is to develop, in conjunction with software vendors, an evolving series of simple and easy to implement platforms that allow the demonstration, simulation, and serious gaming of shift operations at various hubs and cross docks.

The functional design of such a platform should be based on requirements elicited from the practitioners. The intuitions illustrated in the previous section can be used as a starting point in the interaction with the practitioners. The functional design should be always completed with a benchmarking function (McKinnon, 2009) that is supposed to play the role of the real environment of the network. The platform design should be the base of an implementation allowing simulations that have the purpose of testing the appropriateness and

effectiveness of the functions. The final validation of the functional architecture of a potential network wide EIS could be in form of an interactive simulation or even a serious game, where practitioners play their real roles in the organizations. For example, real planners playing this game can interact when supported by the new functionality. Managers can assess if the process that is simulated and/or gamed via the platform resembles what they know from reality, and the improvements are the expected ones.

A platform that allows for realistic simulation and gaming and also encompasses functionality for collaborative alignment may be complex and difficult to develop. There are also caveats related to the participation of the practitioners – their time to attend games is severely limited, as we have seen in our multi-case study. On the other hand, we also discovered that they are very keen and interested in such kind of platforms – we know that because we have tentatively experimented with early prototypes. The software vendors are in principle interested because they will enjoy the advantage of having a validated functional architecture early, enabling them to develop quickly components for the various logistic operators. Moreover, demo platforms, allowing for also simulation and gaming, can be used for promotion and marketing purposes by the vendors.

4 CONCLUSIONS

Many academic research efforts in road freight transport are today directed towards the "grand" themes, like for example the effectiveness and pay-offs of tracking infrastructures, or EIS architectures for multi-modal transport (Marcucci and Puckett, 2012). However, many "quiet" evolutionary changes are constantly occurring in this field, and researchers who are performing in-depth case longitudinal case studies are those who are the first to be aware of these.

Being part of one of these particular groups of researchers, we take the position that in the transshipment area, many hub facilities and the transportation and supply networks surrounding them are confronted more and more (due to competition, various market factors, and changes in the supply chain management paradigms of many SMEs) with the situation that they work in an almost cross docking operating mode. Our main conclusion after the analysis of the empirical information collected during a multiple case-study is that a new

direction and method for research is needed in this area, one that will reveal the needed functionality for this mode in the EIS of the participating logistic operators.

Our main intuition is that a function enabling a highly collaborative *intention alignment* between the operators is necessary. In order to achieve results fast, our proposal is to develop (maybe with the help of software vendors) relatively simple and easy to implement platforms that allow demonstration, simulation, and serious gaming of operations at hubs and cross docks. These are to be used in cooperative research with practitioners involved in case studies, with the aim to discover the appropriate functions, modes, necessary data, components, interfaces, and the potential combinations of new technologies that will allow hub and spoke systems to operate in the highly efficient operating mode that encompasses the cross docking fundamental features.

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