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Intelligent logistics: Involving the customer

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ABSTRACT

The role of logistics in effective supply chain management is increasingly critical, and researchers and practitioners have recently focused their attention in designing more intelligent systems to address today's challenges. In this paper, we focus on one such challenge concerning improving the role of the customer in logistics operations. In particular, we identify specific developments in the systems governing core logistics operations, which will enhance the customer experience. This paper proposes a conceptual model for customer orientation in intelligent logistics and describes a number of specific developments the authors are involved in.

1. Introduction

This paper concerns the introduction of new logistics technologies, systems and practices to improve logistics processes. We are specifically concerned with improving the role of the customer in logistics as part of these developments. This can relate—for example—to improving the ability for a customer to customise and/or change an order or for the customer to be able to expedite an order if it has been faced with unexpected delays. In this section we provide some general background to the challenges modern logistics is facing and outline a general framework for addressing these challenges. We then identify those areas that are specifically "customer-oriented" and focus the reminder of the paper on this. This paper focuses on distribution logistics although some of the remarks made are also applicable to other logistics functions such as production logistics and procurement.

1.1. The problem

Logistics is increasingly identified as a core element of supply chain management [1] yet it is also subject to an increasing number of challenges which require changes to existing operating practices. Some of these key challenges are:

1. Business efficiency: Increasing focus on "leaner" in industrial supply chains to reduce cost and waste and improve delivery performance. Main effects are to reduce inventory being held and to shift towards Just In Time (JIT) delivery models [2].
2. Uncertain operating environment: Congested transportation routes and complex access leading to uncertainties in collection and delivery times [3].
3. Needs of individual customers: Customers are also demanding the option to change orders after submission, both in terms of order composition and delivery options [4].
4. Market variability and changes: Rise of internet shopping and with it direct purchase from supplier warehouses, increased ranges on offer, vastly increased numbers of small orders, demanding delivery times with guarantees [5].

These challenges are complex and at times are also conflicting. Meeting each of these challenges requires considerable efforts of the part of the logistics provider, and—referring to Fig. 1—the provider must be:

- Cost-effective—able to provide services at a competitive pricing level.
- Robust/resilient—able to absorb disruptions such as delivery delays, employee absences, incorrect order preparation, etc.
- Customer-oriented—able to anticipate and respond to the changing customer base and the changing needs of customers.
- Adaptable—able to change logistics priorities rapidly without due cost increases.

As is indicated by the diagram, these four requirements should not be seen to be stand alone but rather integrated. For example, cost effectiveness critically affects the ability of a logistics provider to be adaptable, resilient and customer-oriented. Further, in order

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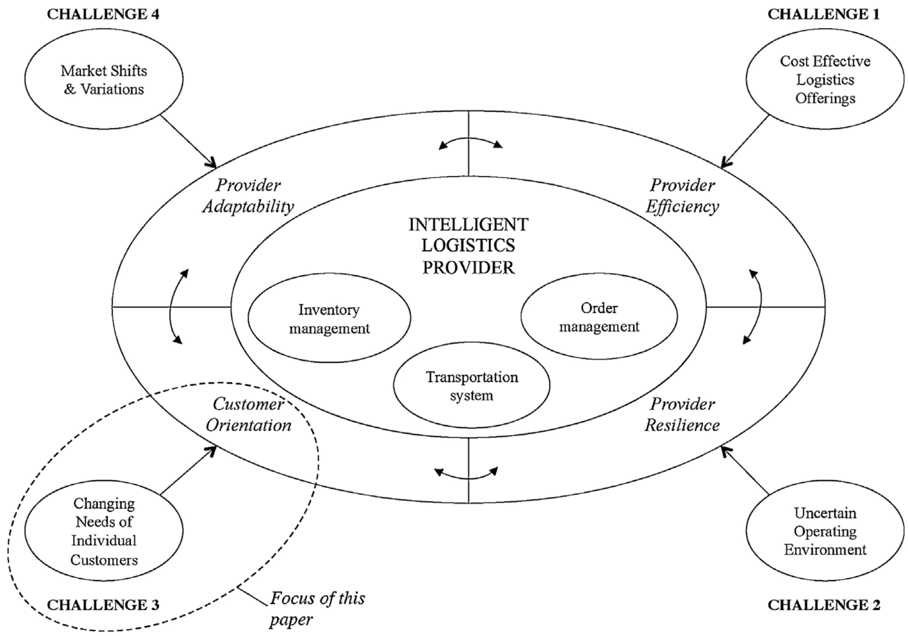

Fig. 1. Meeting today's logistics challenges.

to achieve these capabilities, logistics providers are also seeking to provide more integrated services in which the core operations of order management, inventory management and transportation are seamlessly tied together [1,6]. As in these references, we limit our view of logistics in this paper to those physical operations directly linked to order fulfilment.

1.2. The approach

The approach to be taken in this paper is to develop a simple conceptual model which combines the requirements for customer orientation in logistics with the current development areas in intelligent logistics. The paper then uses this model to identify specific developments in the core logistics operations, which will enhance the customer logistics experience. The aim of the diagram in Fig. 1 is to illustrate that—while it is possible to associate a particular challenge with one of the provider properties—in reality they are all intertwined. For example, the ability of a provider to manage deliveries in an uncertain transportation environment significantly affects his responsiveness to changing needs of individual customers. Hence, although this paper is focussed on Customer Orientation in logistics it is noted that it is rather artificial to separate this challenge from the others. Further, the implication of taking an "Intelligent logistics" approach to achieving greater customer orientation is that much of the developments will arise from improved information management and computer-based decision support.

1.3. The paper

This paper is structured as follows: in Section 2 the backdrop to this work on customer oriented logistics is provided. Perspectives from both academic literature and industrial practice are provided. Then in Section 3 we outline a simple, conceptual model for customer orientation in intelligent logistics, identifying specific systems developments needed to fully achieve customer-oriented intelligent logistics (COIL). Section 4 then describes a number of specific developments the authors are involved in which address aspects of the COIL agenda. The final concluding section then summarises what is still missing in the field and provides next steps.

2. Background

2.1. Overview

In this section, we will review academic and industrial developments related to intelligent logistics and particularly those aspects of intelligent logistics concerned with customer-orientation.

The academic literature will be examined from the point of view of intelligent logistics generally, and also the development of customer-orientated practices. We also review aspects of logistics research relating to adaptability and resilience because these directly link to the ability of a logistics provider to support customer orientation. Similarly we broadly review industrial developments relating to these themes noting that the ICT support for logistics and its ability to flexibility adapt is critical to addressing the challenges mentioned in Section 1. We conclude the section by identifying opportunities to improve current logistics practices.

2.2. Academic literature

2.2.1. Intelligent logistics

Even though the term *intelligent* or *smart* appears very often in the logistics, and more broadly in the supply chain management literature, there is no widely acceptable definition for the notion intelligent logistics. In the related literature, the terms *intelligent logistics* or *smart logistics* are often used to refer to different logistics operations (inventory, transport or order management) which are planned, managed or controlled in a more intelligent way compared to conventional solutions. Moreover, the type and level of the intelligence varies among applications and methods, ranging from product tracking and environmental sensing, to problem recognition and automatic decision making and execution.

Nevertheless, there is a number of approaches which aim to improve logistics systems by making them more intelligent: autonomous logistics [7], product intelligence [8], intelligent transportation systems, the physical internet [9], intelligent cargo [10] and self-organising logistics [11] are some of them. Among these examples, the area of intelligent transportation systems, focusing on transport and traffic management using information

Table 1
Intelligent logistics approaches.

Approaches	Short description
Autonomous logistics	Autonomous control describes processes of decentralised decision-making in heterarchical structures. In logistics systems, autonomous control is characterised by the ability of logistic objects to process information, to render and to execute decisions on their own [7]
Product intelligence	A physical order or product instance that is linked to information and rules governing the way it is intended to be stored, prepared or transported that enables the product to support or influence these operations [8,13]
Physical internet	The physical internet (PI, π) is an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols. The approach suggests exploiting the digital internet metaphor to develop a physical internet vision toward meeting the global logistics sustainability grand challenge [14,9]
Intelligent transportation systems	Intelligent transport systems aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated and 'smarter' use of transport networks [12]
Intelligent cargo	A cargo-centric approach with cargo having capabilities such as self-identification, context detection, access to services, status monitoring and registering, independent behaviour and autonomous decision making [10]. Research related to the intelligent cargo initiative has been conducted in many EU projects, e.g. e-freight, EURIDICE, COMCIS [15]
Self-organizing logistics	When a logistics system is self-organizing it can function without great intervention by managers, engineers, or software control [11]

and communication technologies [12], has attracted the greatest interest during the last years as its scope is broader than the logistics of products only. These approaches are summarised in Table 1.

2.2.2. Customer orientation in logistics

There are three main aspects affecting the extent of customer orientation achieved in supply chains [4]: *customer-closeness*, *customer-flexibility* and *customer-accessibility*:

1. *Customer-closeness*: the extent to which a supply chain displays readiness to keep in contact and effectively communicate with customers. Moreover, the extent to which supply chain organisations can understand and perceive the customers' changing needs and requests over time, throughout the entire supply chain.
2. *Customer-flexibility*: the extent of awareness and the intent of firms to respond to changing customer expectations. These firms understand the needs for building internal design, manufacturing and service capabilities in view of rapidly changing customer tastes and preferences.
3. *Customer-accessibility*: the extent to which a supply chain is ready to allow customers to access information that is critical in fulfilling their multiple requirements. This aspect requires an operational strategy for developing effective operational and service delivery systems for customer contact, thus making information available according to customer needs.

Besides the above definition, there are also other ways to understand the notion of customer orientation in supply chain management and logistics. One of them is through the study of the academic and industrial frameworks developed and used for the measurement of the performance of supply chain companies. In many of these frameworks, the importance of the customer stands up since the 'customer' aspect is usually recognised as one of the factors affecting the performance of a company or a supply chain as a whole [16–21]. Moreover, conceptually, customer orientation in logistics is close to the concept of the *perfect order*. The perfect order paradigm attempts to more directly capture customer satisfaction by tying multiple measures to a single order and highlights the fact that customer perceptions of logistics performance many times differ from those of the provider [22,23,21]. Finally, there is also common ground between customer-orientation and the "voice-of-the-customer (VOC)". In simple terms, VOC is generally used to refer to the customer's real needs, requirements, opinions and reclamations [24], and it is used to highlight the importance that these attributes are known and are considered by companies. Even though the term was initially introduced in manufacturing, it also appears in the supply chain management literature along with customer-orientation and satisfaction [25].

In this study, we adopt the generic definition provided in [4] for customer orientation and we describe an organisation offering *customer-oriented logistics* as one that focuses firstly on customer-related measures paragraphs and aims to mainly satisfy its customers' logistics needs. This definition does not imply that a customer-oriented logistics organisation fails to perform well in terms of other non customer-related measures. It rather highlights the fact that compared to *organisation-oriented logistics* where organisations measure their performance mainly in terms of incoming revenue and cost efficiency, customer-orientation focuses on the satisfaction of each customer. For example, in organisation-oriented logistics a warehouse company would aim to minimise the average picking time of its pickers although in customer-oriented logistics, the company would target at the minimisation of orders that leave the warehouse too late to be delivered in time.

2.2.3. Flexibility and resilience

Logistics flexibility is particularly important and interesting from the perspective of improving customer involvement. The importance of flexibility is clear from several performance measurement systems that place it under customer-related factors: flexibility of service systems to meet particular customer needs in [18,19], agility (flexibility and adaptability) in [21], flexibility and responsiveness in [17]. In logistics in particular, the term describes the ability of a firm to respond quickly and efficiently to changing customer needs in inbound and outbound delivery, support, and services and it has four components [26]. Fig. 2 depicts the role of each component in logistics flexibility and provides short descriptions for each one of them.

Besides its contribution towards greater customer satisfaction [26], flexibility is also enhancing the resilience of logistics providers [27]. Flexibility is considered among the those logistics capabilities that can help a logistics company become more resilient and ready to respond to disruptions and disruptive events [28]. Therefore, a provider with high levels of flexibility can not only provide logistic services that increase the satisfaction of their customers but also use these competences and capabilities to manage risks and unexpected events.

2.3. Related industrial developments

Logistics providers and retailers are increasingly trying to offer their customers greater control over their orders and shipments.

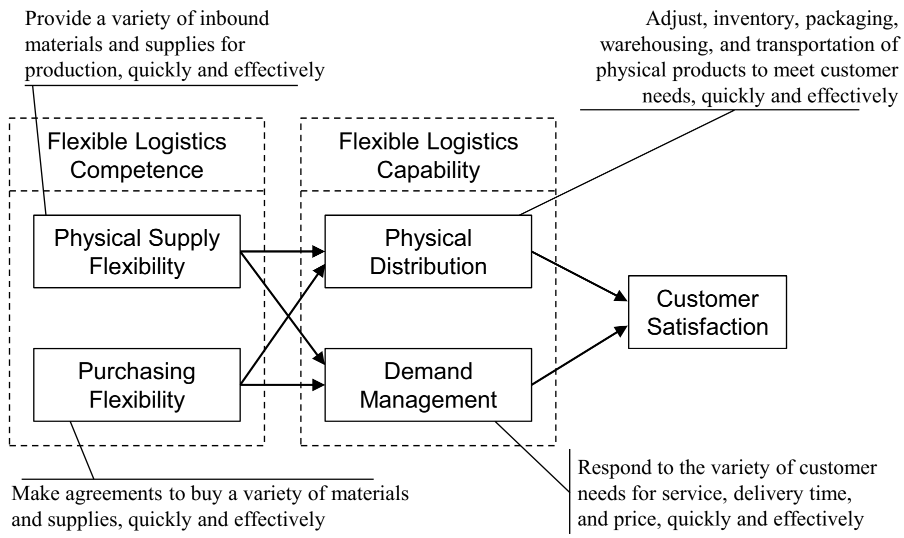

Fig. 2. Flexible logistics framework.
Adapted from [26].

Two recent and well-established developments come from two leaders in the courier delivery services industry. UPS with the My Choice® programme [29] and FedEx with Delivery Manager℠ [30], both aim to give customers a greater level of flexibility and customisation over their home deliveries. Highlighting the importance of customer convenience, these programmes provide a wide range of features in on-line platforms that help customers manage deliveries to suit their schedules. Among others, these features include re-routing to a different address, re-scheduling a delivery date or providing delivery instructions in the case of a customer's absence. Interesting developments from the retailers' side in this area come from Tesco and Amazon. Both companies allow their customers to cancel or amend the details of placed orders (contents, address, shipping method) up to the point when these orders enter a planning [31] or shipping [32] stage.

Resilience has been recognised as one of the main next frontiers in supply chain management by industrial organisations too [33]. In a recent white paper, C.H. Robinson, one of the world's largest third party logistics provider argues that although improving efficiencies and cutting costs will remain a priority in the logistics industry, identifying risks and developing resilience plans will be very high in the agenda [33]. An example programme focusing on resilience is DHL's 'Resilience360' which helps companies to monitor and asses the impact of potential disruptions in their supply chains [34].

In an attempt to provide more cost-effective and at the same time adaptable services, logistics providers have introduced integrated logistics solutions which aim to simplify supply chain complexities. An example is Kuehne+Nagel's integrated logistics programme which offers services that span from sourcing and making to delivering and servicing [35]. Similarly, Kerry Logistics offer integrated, end-to-end supply chain management solutions in the Asian market aiming at cost-effective logistics services [36].

2.4. Summary and opportunities

The conclusions we can draw after reviewing the academic literature and related industrial developments are:

1. Changes in the customer base and the operating environment linked to logistics is currently outstripping the technical developments being introduced in this sector, except for limited developments used by market leaders. The result is bespoke, localised solution being put in place to enable—for example—the needs of individual customers.
2. Traditional logistics software packages (WMS, TMS, etc.) are limited in their ability to support the highly customer-oriented environments and services being promised by internet-based retailers.
3. The flexibility of transport providers is significantly limited by their ability to accurately track orders and, where necessary, change the routing and priority of orders.
4. The cost impact of being adaptable, resilient and customer-oriented is not well understood and yet represents decisions made on daily basis by logistics providers.

From these conclusions it appears that there is opportunity to motivate and direct developments in (intelligent) logistics systems from a customer-oriented perspective. As well as there being a clear need for alternative technological solutions in this area, a customer-oriented approach to shaping intelligent logistics will ensure that the new developments will provide direct customer (and hence provider) benefits.

3. A conceptual model for customer orientation in intelligent logistics

Motivated by the opportunities identified in the previous section, we now introduce a simple model for describing how customer orientation can be embedded into an (intelligent) logistics system. We then drill down into this model to identify specific development areas requiring attention. We emphasise that the primary aim of the model is to clarify and define this development path rather than be comprehensive on its own.

3.1. Elements of intelligent logistics

As a preliminary, we begin with a definition. In Sections 1 and 2 we provided introduction to some of the numerous efforts to create more intelligent logistic operations. We state here the working definition of Intelligent Logistics we will use for the remainder of this paper.

Working definition (Intelligent logistics system).
An intelligent logistics system is one whose information management and automated decision support enables the following properties:

1. Awareness: the system is (automatically) aware of its own state.
2. Integration: the key operations of the logistic system are integrated, such that their planning and execution are effectively coordinated.
3. (System) Adaptability: the system is able to adapt the way it operates depending on changes in the operation environment.
4. (Customer) Modifiability: customers are able to modify order details before and after order release.

The aim of this definition is to place the notion of "intelligent logistics" in terms of the properties of the resulting logistics operation rather than the underlying IT technologies.

Also, referring to Fig. 1, we noted earlier that logistics operation can be usefully decomposed into [1]:

- *Inventory/warehouse management*: goods storage, order picking, order assembly and packaging.
- *Transportations/goods movement*: goods collection, transporting, good receipt.
- *Order management*: order receipt, order assignment, order scheduling, order execution, order tracking.

Hence for each of these three operational areas, an "intelligent systems" approach would involve the introduction of properties of self-awareness, adaptability, modifiability through enhanced information management and/or automated decision support.

3.2. A customer-oriented intelligent logistics model

The model we develop here is simply to provide a connection between customer orientation and intelligent logistics. In Section 2 we introduced the work of Jeong and Hong [4] in which they define three key factors in customer orientation: (a) closeness, (b) flexibility and, (c) accessibility. Combining these three factors with the three domains of logistics operations discussed in Section 3.1, Fig. 3 suggests a simple conceptual model for ensuring the customer oriented needs are effectively included within a providers intelligent logistics system. The model suggests that customer-orientation must be all pervasive throughout the logistics operation not just at the key customer interfaces points: order placement and goods receipts. In the next section we will analyse what it means to achieve this conceptual model in greater detail, examining what is required to provide pervasive customer orientation throughout each of the logistics provision operations.

3.3. Functionalities of COIL

Table 2 outlines a detailed set of properties for a successful customer-oriented intelligent logistics (COIL) model. Each requirement in the table is given a requirement number—e.g. R11a—in order that it can directly be referred to in Section 4. We examine the table, one row at a time.

1. Closeness: Closeness refers to the level of contact a logistics provider keeps with his customer in order to understand his requirements. In transport management, this implies that a customer's requirements regarding the delivery and handling of his orders are anticipated. In inventory and order management, order delays and delivery problems are detected in advance, conveyed to the customer and managed accordingly by the logistics provider. At all times, the customer is in a position to express his needs to the logistics provider.
2. Flexibility: The role of logistics flexibility refers to the ability of a firm to respond to changing customer needs. A flexible logistics system is therefore capable of adapting itself to satisfy new orders or changing priorities. More specifically, flexibility offers the customer the opportunity to customise and modify his delivery or order preparation choices as well as estimate the required cost of these modifications.
3. Accessibility: This functionality involves ensuring the customer is in close contact with his/her order, its location and state of completion. This implies that the customer can see real-time inventory in all provider's storage locations. Furthermore the customer has access to tools that allow him to monitor a track an order during transportation or preparation. Finally, the alternative options for handling his orders are available to a customer and described in terms of their cost and time.

The entries in Table 2 are the result of industrial requirements studies with industrial logistics providers over a number of years. The table, however, is under continuous review as the needs of the customers evolve. These requirements are not sector-specific

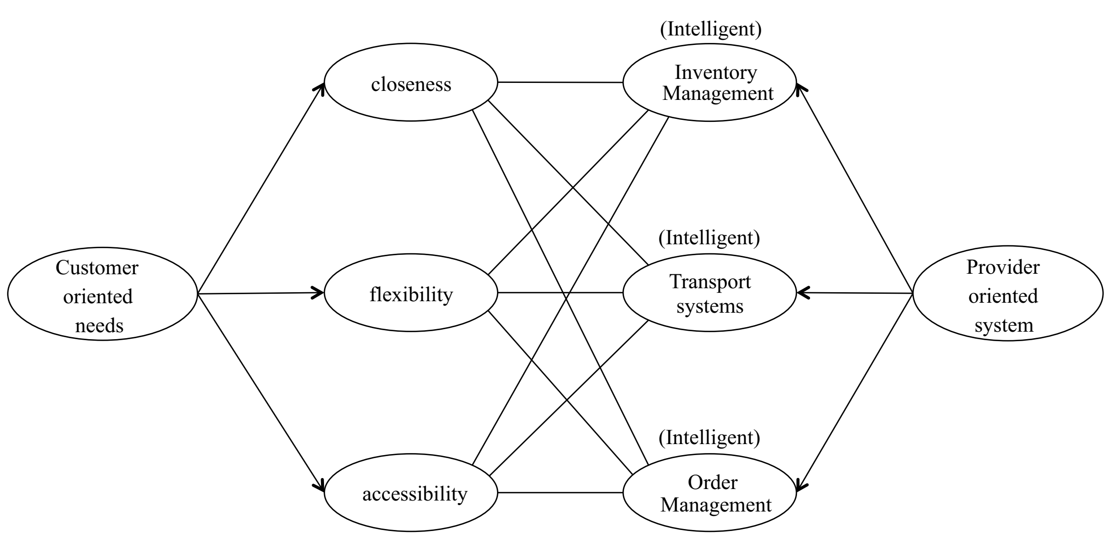

Fig. 3. Conceptual model for customer orientation in intelligent logistics (COIL).

Table 2
System requirements for customer orientation in intelligent logistics provision.

	"Intelligent" inventory management	"Intelligent" transport management	"Intelligent" order management
Closeness	• Customer is able to adapt order in process [R11a] • Provider detects potential order delivery problems and adjusts order preparation [R11b]	• Customer delivery requirements anticipated [R12a] • Customer order(s) handling anticipated [R12b]	• System anticipates order delays and conveys to customer [R13a] • System aggregates/disaggregates customer orders as needed [R13b]
Flexibility	• Storage arrangement matching demand [R21a] • Order-picking system adapts to new orders, priorities [R21b]	• Provision of narrow, customise delivery arrangements [R22a] • System can adapt delivery of order during delivery (location, time) [R22b]	• Order management system capable of adjusting to meet new demands [R23a] • Order costing model adjusts with demands placed on it [R23b]
Accessibility	• Customer has full visibility of quantities of goods in storage at all locations [R31a]	• Customer has full visibility of progress of order delivery [R32a] • Customer has visibility of all alternative delivery options and pricing [R32b]	• Customer has full visibility of state of order [R33a] • Customer can immediately see time/cost implications of changes to order [R33b]

although some of them can be more applicable (or more important) in certain industries/sectors.

4. Developments towards a COIL model

Table 2 provide a model and set of requirements for a logistics system to be able to address the multiple requirements of customer-orientation within its overall functionality. Essentially, a framework for ensuring key aspects of Customer Oriented Intelligent Logistics are addressed. In this section, to illustrate the applicability of this framework, we describe a series of developments being undertaken by the authors which contribute to a Customer-Oriented Intelligent Logistics (COIL) system. The developments include both customer and supplier oriented system developments and address rationale and benefits for such developments as well as technical approaches, and each development is linked to the appropriate section of Table 2. Further, Figs. 3 and 4 outlines the logical process that is being used to guide the development—in conjunction with the requirements provided in Table 2. The process identifies three main research topics in the COIL area: (a) conceptual models that explain the meaning of COIL, (b) evaluation of COIL services, and (c) technical implementation of COIL systems. For each topic we list a number of questions that need to be answered towards the development of a COIL system.

The following sections provides a brief introduction to a series of COIL developments in the authors' institution. In each case, the

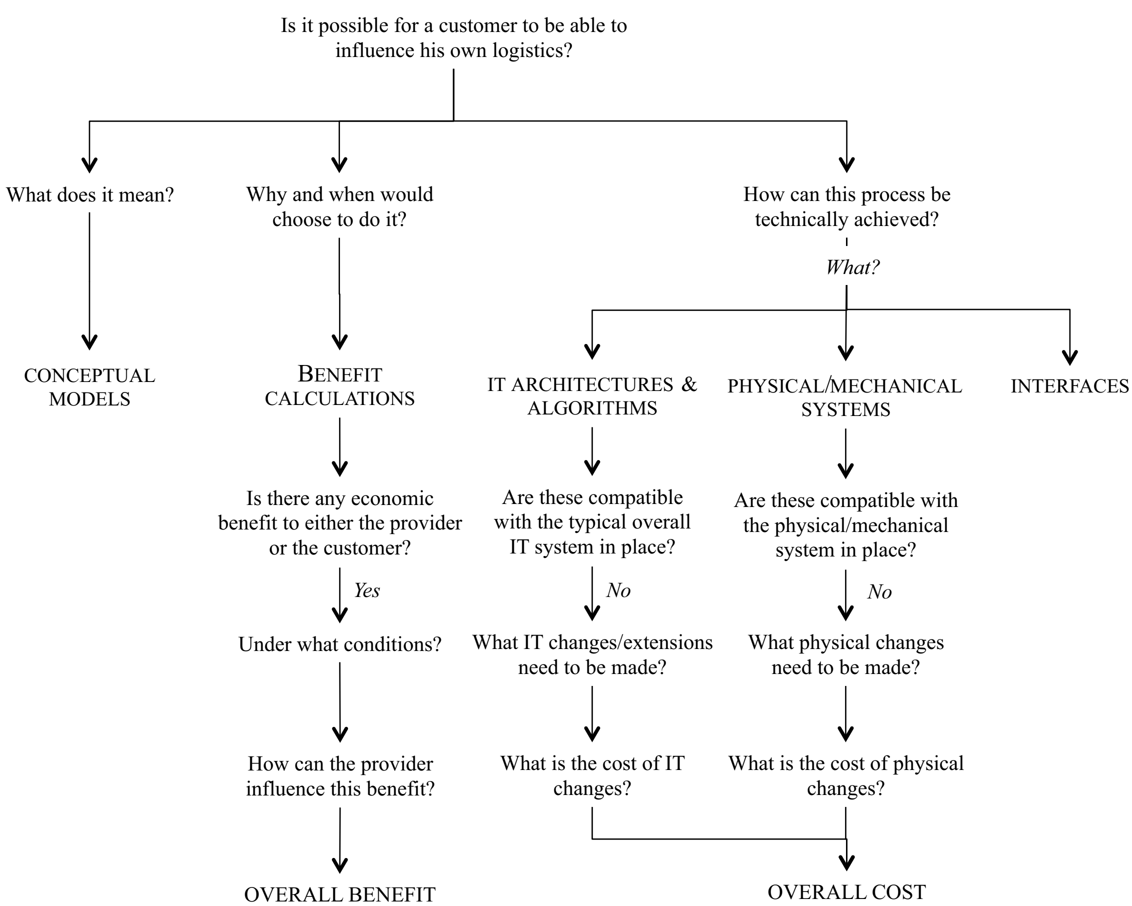

Fig. 4. Logic used to guide COIL development.

work is linked with the requirements of Table 2. Further details on each section are provided in other (referenced) papers.

4.1. Intelligent products for managing customer orders [R23a, R33a, R33b]

Using automatic identification and data capture technologies, product intelligence [37,38,13] allows products to be uniquely identified and interact with their environment (systems, products, people) to gather and store information for instant or later use. More importantly, products can acquire some level of intelligence via their linkage with software agents, in order to be capable of making decisions. As a result, in a logistics system using a product intelligence approach, physical items are capable of influencing the way they will be handled, potentially by allowing a customer to directly influence these operations. This is illustrated with a simple example in Fig. 5 in which a warehouse order generates an intelligent software agent to "accompany" the order through picking. Here, an intelligent product dynamically updates the route of a picking operator after a customer amends the order he has already placed by adding more products in it.

A number of issues in the area of product intelligence for logistics [43–49] have been examined by the authors of this paper, as well as their research associates, some of which are discussed in more detail next. The contribution of product intelligence towards customer-orientation in intelligent logistics is that it can provide a suitable platform for the development of systems offering closeness, accessibility and flexibility. A logistics provider considering product intelligence to enable customer-orientation could reasonably use it in order to allow its customers to (*a*) access data about their current and previous orders, (*b*) express their changing needs and preferences and ultimately (*c*) make new decisions among a set of available options when needed.

4.2. Resilient industrial control and order management [R11b, R21b, R23a]

A collaborative project with the Boeing company is investigating the potential for intelligent order tracking and management to interact with automated production and inventory management systems [50–52]. The order tracking system is designed to interface between the customer order and the resources for inventory management and production. In particular, delays are implicitly acknowledged and the operations adapt to minimise the likelihood of order delivery delay.

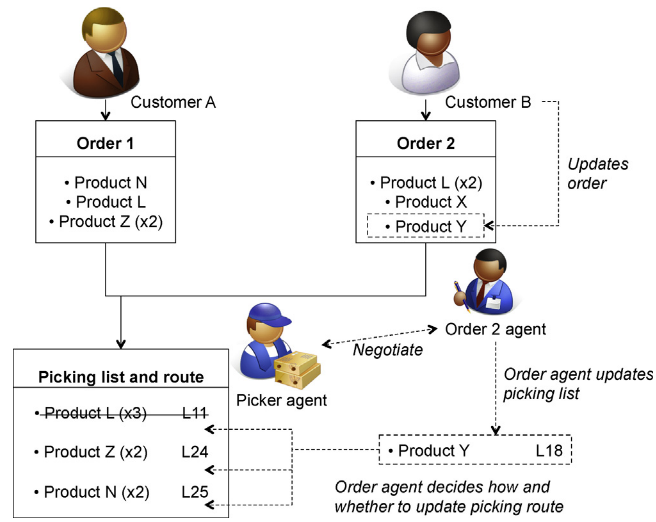

Fig. 5. Example of product intelligence managing customer orders.

A working demonstration incorporating flexible inventory storage and retrieval has been developed around an assembly operation (see Fig. 6). Experimentation will be carried out on this demonstration system in 2015 to evaluate the effectiveness of these order management and flexible inventory strategies.

4.3. Interventionist routing algorithms [R11a, R21b, R23a]

In order to support customer orientation from the logistics providers' point of view, the resilience of theirs operation need to be enhanced. In warehouses, order-picking is normally scheduled based on the known customer orders that form pick-lists to guide order-pickers [39]. This results in systems with low levels of resilience since amendments, cancellations, new and urgent orders cannot be handled during the picking operation. An alternative which would both improve resilience and provide a customer-oriented environment would be an Interventionist Order-Picking (IOP) strategy that can adapt itself to new orders and requests.

A fundamental element of an IOP strategy is an algorithm that calculates the route of minimised distance an order-picker should follow, upon receiving updated information on the requested items of new orders during the picking operation. The Interventionist Routing Algorithm (IRA) has been proposed for this reason

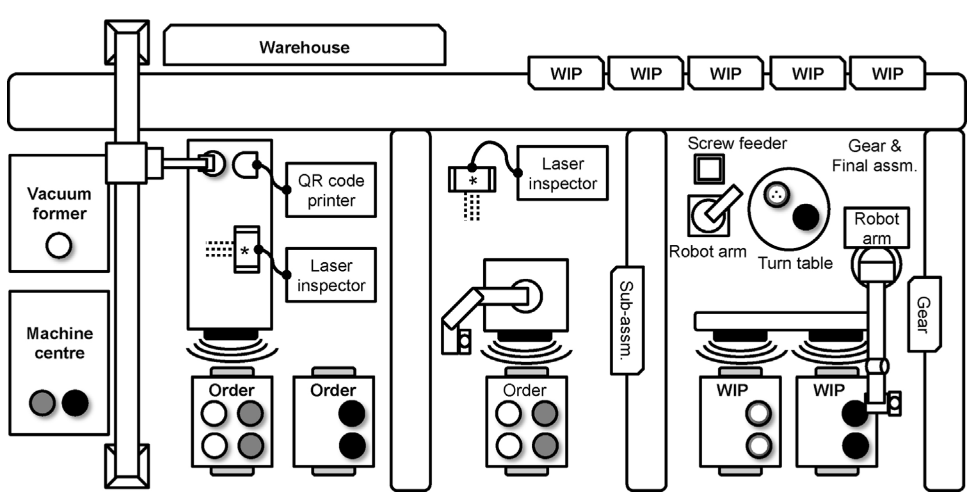

Fig. 6. Assembly operation designed for evaluating order management and flexible inventory strategies.

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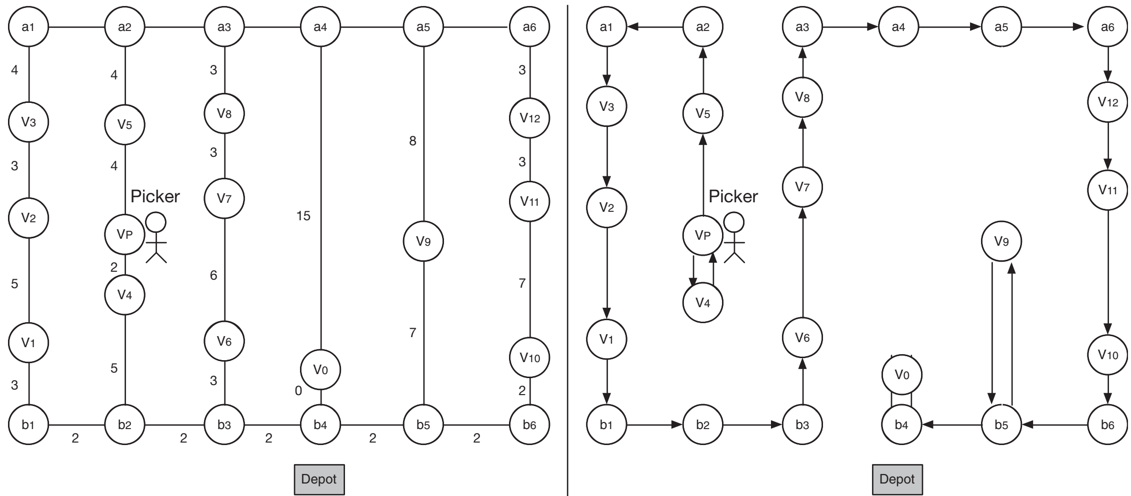

(a) Graphof the order-picking layout

(b) Optimised order-picking route

Fig. 7. Example for applying IRA.

[53]. IRA adapts a similar approach as in well-established routing algorithms for order-picking [40] to develop an efficient procedure using graph theory for examining all feasible routes, and then determine the one with minimum length (see Fig. 7) for an example. This development addresses four main criteria required when re-routing an order-picker in an IOP strategy: (a) interruptibility, (b) optimisation, (c) complexity and (d) centralised depositing. Current results indicate that under a range of conditions, the proposed interventionist routing algorithm can outperform both static and heuristic dynamic order-picking routing algorithms [53].

4.4. Adaptive storage location assignment [R21a]

Currently, there are many ways that storage location assignment can be conducted in warehouses, however, none of those is adaptive to (increasingly frequent) changes in the customer demand [39,41]. In collaboration with James and James, an e-commerce order fulfilment company, an adaptive storage assignment strategy aiming at updating storage arrangements to match demand was developed by the authors [49]. The strategy constantly calculates the optimised storage location of newly arrived items, based on the current status of the warehouse and the historical data at the time of arrival. Similar to other storing strategies, our adaptive strategy aims to improve picking performance by minimising the travel distance a single product needs to cover from its storage location to the depot when requested in an order. Initial results demonstrate a benefit on the average travel distance per item that reaches 22% inside the picking area of big warehouses.

4.5. Coordinated inventory and transportation management [R11a, R21b, R12a]

In order to fulfil an order in a warehouse, a sequence of three decisions is typically required [41]: (a) how to assign the order to an outbound transport for delivery (i.e. transportation management), (b) how to select a storage location to fulfil the order (i.e. inventory management), and (c) how to choose a picker to pick the product that is requested by the order (i.e. picking management).

Conventionally, these decisions are made independently with no or little coordination between them. This decoupled approach works acceptably well if all the order information is known in advance. However, in customer-orientated logistics, the above decisions are made under uncertainty since the inter-arrival time of orders (or other requirements such as order amendments) is stochastic by nature [42].

In order to enhance the flexibility of the operation in customer-oriented logistics, the authors believe that more opportunities can be identified by investigating the impact between these three decisions and the coordination among them. Therefore, centred by the intervention style for the order-picking management using IRA, transportation and inventory management is modelled using a Markov decision process based approach. With the information of the newly received orders as well as the status of the three processes, the model is expected to output a solution of fulfilling the order with the lowest cost. As a result, a cost, that is based on the real-time status of transportation, inventory and picking, can then influence the price offered to the corresponding customer.

4.6. Benefits calculation of flexible logistics offering [R23b, R32b, R33b]

From a customer's perspective, flexibility in customer orientation is perceived via the *flexible logistics offerings* provided to him. The component mix of these offerings (physical, price/cost, service) is flexible to changes in order to respond quickly to new customer expectations or needs.

In order to evaluate the potential benefits of flexible logistics offerings, a model was designed to compare them with conventional, fixed offerings whose details are fixed upfront when an order is placed [54]. The model compares fixed and flexible logistics offerings by examining the interactions emerging between providers and customers in each case. The model can be used to determine the conditions under which each or both parties can benefit from providing or using a flexible logistics offering. It can also be used, alongside a set of guidelines, to compare and analyse the different pricing models can influence the value flexible logistics offerings can deliver.

The basic structure of the game theoretic model along with the payoffs for the provider and the customer are presented in Fig. 8. The outcome of the game—and thus the payoff each party will receive—will depend on the availability of logistics services a customer can choose from initially as well as on other conditions such as cost for amendment, probability of disruption and probability of adequacy of the provider's current plan. Our analysis

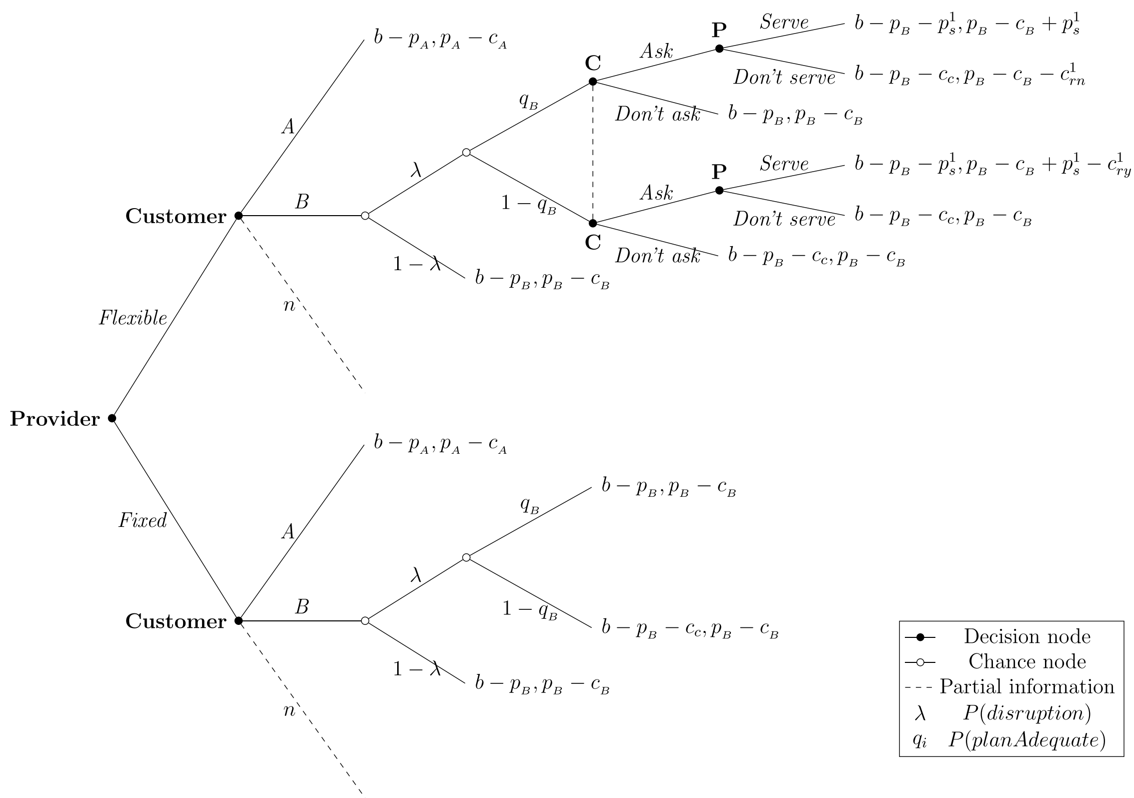

Fig. 8. Game theoretic model: example with payoffs.

using the model confirms that flexible logistics offerings can be beneficial both for the provider and the customer at the same time. Moreover, it highlights the importance of pricing flexible logistics offerings for their adoption and usage [54].

4.7. Adaptable transportation routing [R12a, R22b, R32a]

Outside a warehouse, a customer might wish to amend the details of his orders whilst in-transit. These amendments normally refer to a change in the delivery address or date. In such cases, a customer order or shipment will need to be dynamically re-routed within a transportation network [44]. Inspired by the way humans treat disruptions during journeys in multi-modal networks that require re-routing decisions, we have previously examined how use product intelligence to mirror (and then automate) human decision making in freight transportation [43]. In order to understand human decision making in more detail, a simulation game was designed to capture and analyse “why” and “how” people make certain decisions.

The simulation game requires players to travel through several terminals in a multi-modal transportation network before they can reach their final destination. The players journeys are disrupted by random unexpected events while in transit. In such cases players need to decide the best way to deal with these disruptions choosing between waiting in terminals or re-routing themselves. The results of the experiments using the game reveal many interesting strategies used by travellers that could be replicated in and potentially benefit freight transportation. Among them is the idea of constantly re-evaluating transportation routes along with their risk even if there is no particular transportation or customer request that needs to be accommodated. In this way, a logistics provider will be ready to make appropriate changes faster when and if needed.

An interesting observation from the authors’ involvement in this activity has to do with the necessary operational process that need to be in place to facilitate re-routing. Unlike people who are able to physically execute their decisions (e.g. move from one place to the other in a terminal), products can not control themselves physically. Therefore, besides an approach that recalculates optimal routes at the order-level, it is also mandatory to investigate how new decisions will be executed in the physical world.

4.8. Assessing compatibility of COIL with conventional logistics systems [R11a, R21b, R23a]

An important challenge faced by logistics companies refers to the transformation of their legacy systems in order to satisfy new customer requirements and needs. Especially with the expansion of internet and the acceleration of e-commerce, traditional logistics companies are required to fulfil orders whose nature is significantly different from the ones often placed by big industrial clients [5]. In warehouse management in particular, providers have to deal with orders of smaller size, greater variety and shorter lead times using the same facilities and IT systems developed to serve B2B clients. Consequently, it is important to understand how compatible conventional physical and IT systems are with the systems and algorithms needed to support customer orientation. Logistics providers can then decide between extending/adapting existing systems to satisfy new requirements or investigate new solutions.

In this direction, the authors have been working on a collaborative project with YH Global to understand the emerging customer behaviour and examine the way warehouse management systems should be designed in order to satisfy it. In particular, the characteristics of the orders placed in B2C environments are examined especially in comparison with traditional B2B commerce as well as the logistics services associated with them (e.g. returns, cancellations, premium memberships). The research aims to provide a tool that logistics providers can use to identify the limitations and opportunities of their current operational and IT systems and explore ways to adapt them accordingly. Moreover, we examine the "ideal" solution for these new requirements and ways providers can transition to it from their current systems.

5. Conclusions

This paper has formalised the manner in which greater customer-orientation can be addressed as part of intelligent logistics systems development. This provides a significant opportunity for the intelligent logistics community as customer-oriented functionalities are currently very limited within today's logistics management systems. By providing a simple conceptual model and a more detailed set of requirements, the paper has attempted to scope the range of developments needed. By way of illustration, a number of the developments by the authors are described and it is shown which aspects of COIL requirements they address. Although it is beyond the scope of this paper, we note that it would be possible to examine numerous other developments in this way and hence build up a more comprehensive mapping of current COIL developments. In particular it is noted that a systematic assessment of the benefits of customer orientation is as important as the development of logistics solutions required to deliver this capability.

The evolution of these developments is interesting to watch. In some areas—for example in the "Accessibility" part of customer orientation—many developments are emerging industrially with little or no academic input being required. In the "Closeness" and "Flexibility" areas, order management support tools for customers promise some further near term gains, which will then require providers to pay more attention to warehouse and transport management issues. Migrating developments in the later areas where systems already exist is perhaps the greatest challenge.

The prospects for a greater focus on customers needs in logistics appear to be strong and inevitable. Already commercial logistics providers are exploring innovation such as drone-based delivery and deliveries into the car boot as a means of increasing convenience to the customer. As these, and others, novelties become mainstream of software system that manage logistics operations will need to evolve accordingly. This will mean better (a) more flexibility/customisation in the order management and fulfilment processes and (b) greater adaptability and resilience to change in the core warehouse and transportation operations. It seems highly likely therefore that new development addressing some of the requirements in Table 2 will see their way into commercial logistics system in the coming years.

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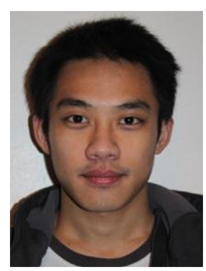

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