Industry 4.0 for Managing Logistic Service Providers Lifecycle

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Abstract. Industry 4.0 (I4.0) can be employed using so called smart information and smart technology to increase customer satisfaction in the global market. Logistics service companies apply I4.0 to create new services or to improve the process, e.g., real-time monitoring system, big data analytics, real-time customer service to keep customer royalty. The aim of this is to implement a new framework for the entire lifecycle of logistics service, i.e., design, test and operation, after sales service and end-of-life assessment. To create and redesign this new service we use Axiomatic Design (AD) to address customer requirements and to manage logistics operation at Logistics Service Providers. As a result, using I4.0 concepts, we can improve the logistics service. Managing the supply chain responsively and increasing customer satisfaction.

1 Introduction

Nowadays, Logistics Service Provider (LSP) is becoming a success factor by improving value added throughout the entire supply chain management and offering service according to the customer needs [1-2]. Since more than 30 years, LSP business have been booming around the world. They assist the manufacturer to smooth their operation and improve logistics efficiency [2]. By including I4.0 in the world of manufacturing and logistics customer requirement can be satisfied more quickly and more effective [3-4]. Internet of Things (IoT) and Cyber-Physical Systems (CPS) are main concepts in I4.0 to meet customer targets by delivering the right products and services in the right time [5]. E.g. web-pages or group chats in their network are becoming the key factors for customer decisions to buy a product or a service.

Servitisation and innovation are powerful tools to change the market and to quickly respond customer needs [4]. Many researchers have attempted to improve business efficiency and to create innovation [6-7], by fulfilling customer needs [8-11] in the entire lifecycle by applying lifecycle management namely; Product Lifecycle Management (PLM), Service Lifecycle Management (SLM) and Product Service System (PSS). Creating strategies to offer customers a fast delivery with appropriate costs and flexible routes are key factors to compete in the global market [12].

AD can be powerful methodologies to re-design and improve logistics service [13-14] using functional requirements to derived from customer needs. In the way we are able to translate the "voice of customer" or "customer needs" [15] to appropriate new innovations in logistics. Besides, AD is famous tool to design and develop products and processes in industry. They prioritize solutions to develop or evaluate products or service [14].

The objectives of this paper is to create an I4.0 oriented model of LPS's lifecycle, which will improve and develop logistics service to attain customers. As methodologies we use in this paper AD. As a result, we get suggestions for how LSP can adapt existing or create new logistics services to achieve a better customer response by using new technologies from I4.0 in the whole logistics service lifecycle.

2 Applied Service Design Techniques

2.1 Axiomatic Design Theory

AD is a methodology to design and improve complex systems or products by also using the voice of customers [13]. AD supports the company to generate innovation by reducing limitations in the design spaces through the definition of solution-neutral requirements [15]. AD transforms so called Customer Needs (CNs) to Functional Requirements (FRs), Design Parameters (DPs) and Process Variables (PVs). CNs are translated to FR identifying what kind of functions are needed and matching this FRs with suitable design solutions DPs. According to Suh AD uses two axioms [15-16]; Axiom 1

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is the Independence Axiom and Axiom 2 is the Information Axiom.

Axiom 1 means that all FRs are fulfilled independently and each DP satisfies only one FR not affecting the other FRs. Axiom 2 means minimizing the information content in case of design alternatives usually by selecting the alternative with the highest probability for success. In Axiom 1 the relationship of FRs and DPs is usually described in form of a design matrix as indicated below in, (1) and (2).

$$\{FR\} = [A]\ \{DP\} \qquad (1)$$

$$\begin{bmatrix} FR1 \\ FR2 \\ FR3 \end{bmatrix} = \begin{bmatrix} A11 & A12 & A13 \\ A21 & A22 & A23 \\ A31 & A32 & A33 \end{bmatrix} \begin{bmatrix} DP1 \\ DP2 \\ DP3 \end{bmatrix} \qquad (2)$$

In AD matrix A is called design matrix. According to obtained design matrix, it is possible to obtain matrix with three kind of design namely, uncoupled, decoupled and coupled [16]. The difference between these designs can be seen in its graphical and mathematical representation. A coupled design is not acceptable and the selection process of DPs must be repeated. A decoupled design is worse than an uncoupled but still allows the exact adjustment of the functional requirement. To satisfy the independence axiom, design matrix must be either diagonal (uncoupled design) or triangular (coupled design).

The paper will use AD to create or re-design logistics services to meet the customer's requirements. For the integration of AD to LSPs, this paper identifies in the first step CNs to FRs and constraints. In a second step this FRs are then used to derive appropriate DPs as described in Section 4

2.2 Industry 4.0

The fourth industrial revolution incorporates information technology and networking/connectivity concepts to develop intelligent production and services [17-18] to support customer satisfaction and to improve operations in the whole supply chain [19]. I4.0 is a phenomenon to enhance in every industry the response to the customer by delivering the right product at the right time. The main buzz words used in combination of I4.0 are often CPS, IoT, Internet of Service (IoS) and Smart Factories [20-21].

"Smart Logistics" is defined as the implementation of information and technology to fulfil the complexity of customer service with fast service and the delivery of the right product to the right customer and the improvement of operation efficiency in the supply chain [15,17, 22]. Smart logistics can be separated into two main parts; (i) physical product and (ii) information or data. IoT is a main part to develop logistics service able to visualize real-time information in the supply chain. Radio Frequency Identification (RFID) and Global Positioning Systems (GPS) can be used in logistics service to track and trace products or vehicles based on real-time information [23]. Cloud computing platforms support the customer to detect their product by themselves in real-time [21]. Big- Data and Cloud technology can collect route and traffic information to achieve transportation optimization [24].

3 LSP's Lifecycle Model

3.1 Introduction in the LSP's Lifecycle Model

This research uses LSP's Lifecycle Model developed by Tiwong and Ramingwong [25]. The LSP's Lifecycle Model is characterized by three phases, eight criteria and seventeen sub-criteria as shown in Figure 1. Phase one is called "beginning of life" (BOL) as a first stage for creating strategies and innovations to identify customer requirement [26]. There are three parts namely; research/idea, design/test and long-term relationship. Research/idea evaluates the opportunity to improve or launch new products or services [27-29]. "Middle of life" (MOL) is a second phase of characterized by operations performance and financial performance. The "end of life" (EOL) is the last phase in the proposed model. There are three criteria namely; risk management, evaluation and end of life decomposition [30-31]. The whole LSP lifecycle phases need to be coordinated to offer LSP's clients improvements.

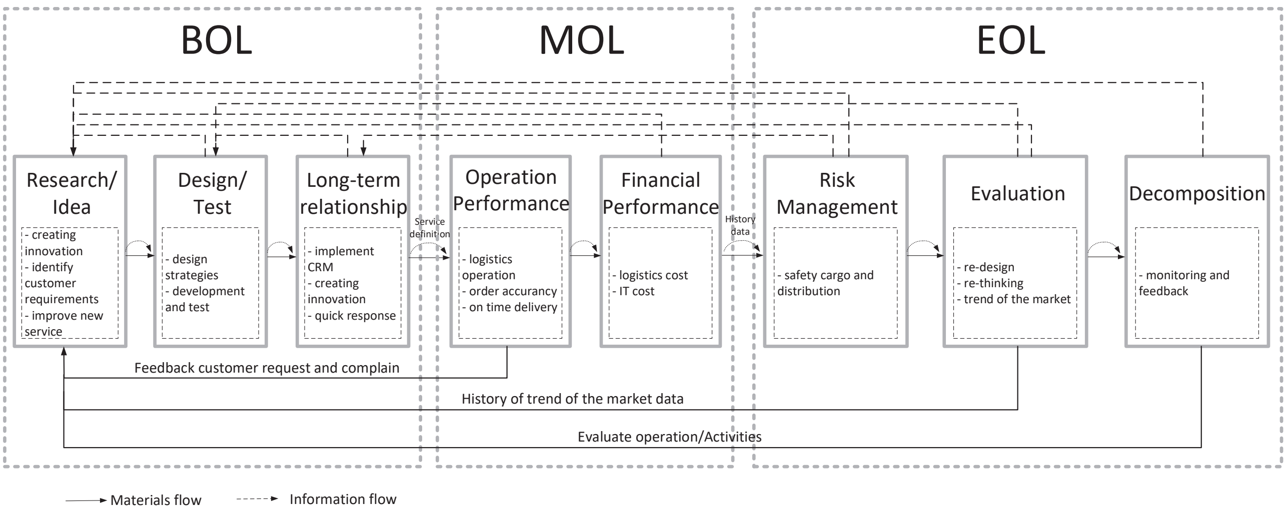

Fig. 1. Interactions and relations in the proposed LSP's Lifecycle

Feedback regarding customer requirements and customer satisfaction are information obtained from MOL stage to improve design and strategies at BOL stage.

3.2 Customer Requirements in AD

LSPs offers a complete service to satisfy the customer needs. The adaptation and evaluation of processes or activities in the logistics service are highly applicable [32-33]. They involve not only cost, time and reliability, but also service attitude, service convenience and professionalism [34]. AD is used as selecting method, which addresses customer requirements to solve the complexity problem through the best solution. The adaptation of AD is to create and redesign services to improve LSP's lifecycle, using customer requirements or the voice of customers as input data. In the following Section 4 we describe eight FRs based on eight identified CNs and the derived DPs by using AD.

4 The Axiomatic Design for the integrated requirement for LSPs

In this research, we apply AD to find the best solution for the design of new LSP services. There could be identified eight main CNs:

- CN1 = Creating innovation service
- CN2 = Design to meet customer requirement
- CN3 = Long -term relationship
- CN4 = Operations performance
- CN5 = Financial performance
- CN6 = Risk management
- CN7 = Evaluation of customer satisfaction
- CN8 = End of life decomposition

In a next step we translate CNs to FRs and derive DPs to create the new services. A table is used to illustrate the decomposition of identified FRs into DPs (Table 1.). As indicated in Table 1 FRs have sub-FRs addressing the logistic operations.

The design matrix shows the relation between FRs and DPs to apply the independence axioms (see (3)).

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \\ FR_4 \\ FR_5 \\ FR_6 \\ FR_7 \\ FR_8 \end{Bmatrix} = \begin{bmatrix} x & o & o & o & o & o & o & o \\ o & x & o & o & o & o & o & o \\ o & o & x & o & o & o & o & o \\ o & x & o & x & o & o & o & o \\ o & x & o & x & x & o & o & o \\ o & o & o & o & o & x & o & o \\ o & x & x & x & o & o & x & o \\ o & o & o & o & o & o & o & x \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \\ DP_4 \\ DP_5 \\ DP_6 \\ DP_7 \\ DP_8 \end{Bmatrix} \quad (3)$$

The above-illustrated results show relations of FRs and DPS on the first level of decomposition in Axiom 1. There are coupled designs. For example, FR4 "Improve efficiency of logistics operation" is related to DP2 "Validated strategies to increase customer satisfaction" and DP4 "Operations Management". For the example of FR4 and DP4, there are many possible substitutes for consultation of FR4. The detail of FR4 can be separated in level 2 in FR4.1 "Increase order accuracy", FR4.2 "Increase on time delivery accuracy and reduce damage rate" and FR4.3 "Collect real-time information of logistics operation".

Table 1. FR-DP decomposition for LSP's Lifecycle Model

Translated Functional Requirements (FRs)		Derived Design Parameters (DPs)	
FR	**Optimize time, cost, reliability and innovation for customer satisfaction**	**DP**	**LSPs Lifecycle Model**
FR1	Collect and analyse data from customer suggestion and marketing data	DP1	Opportunity analysis for customer requirement
FR1.1	*Identify customer requirements and oppurtunities to generate new service*	*DP1.1*	*Marketing information and demand forecasting to predict new services*
FR1.2	*Innovate existing service to increase customer satisfaction*	*DP1.2*	*Analysis of market demand data and technical requirements*
FR2	Design and test service to satisfy customer requirements	DP2	Validated strategies to increase customer satisfaction
FR2.1	*Understand the added value for the customer in service innovation*	*DP2.1*	*Service concept to maximize customer satisfaction*
FR2.2	*Design the new/adapted service offer*	*DP2.2*	*Service model and business strategy*
FR2.3	*Test the new service for practical applicability*	*DP2.3*	*Digital mock-up and test setup for testing new services*
FR3	Implement CRM initiation	DP3	Flexible services to support customer
FR3.1	*Focus long term partnership*	*DP3.1*	*Service to support the customer in the whole lifecycle*
FR3.2	*Respond quickly to the customer*	*DP3.2*	*Professional and helpful customer service*
FR3.3	*Increase supplier relationship*	*DP3.3*	*Transparent information sharing and collaboration along the supply chain*
FR4	Improve effieciency of logistics operations	DP4	Operations Management
FR4.1	*Increase order accuracy*	*DP4.1*	*Fleet management and alignment with standadization and rules*
FR4.2	*Increase on time delivery accuracy and reduce damage rate*	*DP4.2*	*Delivery data analysis*
FR4.3	*Collect real-time information of logistics operation*	*DP4.3*	*Logistics operation monitoring*
FR5	Reduce logistics cost	DP5	Monitoring of logistic costs and decision making rules
FR6	Analyse and evaluate the risk of warehouse and transportation	DP6	Warehouse and Transporation Management
FR6.1	*Reduce damage rate in warehouse and transportation*	*DP6.1*	*Monitoring and identification of damage rate in warehouse and transportation*
FR6.2	*Return products in case of damages*	*DP6.2*	*Reverse logistics and alignment with standardization and rules*
FR7	Ealuate a and improve service life cycle	DP7	Evaluation model and improvement process
FR7.1	*Evaluate the service life cycle*	*DP7.1*	*Fuzzy-AHP in LSPs lifecycle model based on CRM (history of complains and customer service)*
FR7.2	*Re-design and improve service after evaluation*	*DP7.2*	*Improved Service Model*
FR8	Evaluate the end of life cycle	DP8	End of Life Management (support decline stage and link historical data to DP1 to develop new service innovation)

In level 2 of FR1, we can derive DP1 to meet FR1 in FR1.1 and FR1.2 are DP1.1 "Marketing information and demand forecasting to predict new services" and DP1.2 "Analysis of market demand data and technical requirement" in equation (4). DP1.1 has an effect onFR1.1 and FR1.2 to satisfy the customer. Therefore the design matrix is decoupled in (4).

$$\begin{Bmatrix} FR_{11} \\ FR_{12} \end{Bmatrix} = \begin{bmatrix} x & o \\ x & x \end{bmatrix} \begin{Bmatrix} DP_{11} \\ DP_{12} \end{Bmatrix} \quad (4)$$

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In level 2 of FR2 “Design and test service to satisfy customer requirements” can be separated in FR2.1 “Understand the added value for the customer in service innovation”, FR2.2 “Design the new/adapted service offer” and FR2.3 “Test the new service for practical applicability” deriving DP2.1 “Service concept to maximize customer satisfaction”, DP2.2 “Service model and business strategy” and DP2.3 “Digital mock-up and test setup for testing new services”. These design parameters can create strategies to support customer satisfaction as following in (5) showing an uncoupled design.

$$\begin{Bmatrix} FR_{21} \\ FR_{22} \\ FR_{23} \end{Bmatrix} = \begin{bmatrix} x & o & o \\ o & x & o \\ o & o & x \end{bmatrix} \begin{Bmatrix} DP_{21} \\ DP_{22} \\ DP_{23} \end{Bmatrix} \quad (5)$$

The matrix in (6) shows the decoupled design in level 2 of FR3 “Implement CRM initiation”, which can be separated in FR3.1 “Focus long term partnership”, FR3.2 “Respond quickly to the customer” and FR3.3 “Increase supplier relationship” deriving DP3.1 “Service to support the customer in the whole lifecycle”, DP3.2 “Professional and helpful customer service” and DP3.3 “Transparent information sharing and collaboration along the supply chain”.

$$\begin{Bmatrix} FR_{31} \\ FR_{32} \\ FR_{33} \end{Bmatrix} = \begin{bmatrix} x & o & o \\ x & x & o \\ x & x & x \end{bmatrix} \begin{Bmatrix} DP_{31} \\ DP_{32} \\ DP_{33} \end{Bmatrix} \quad (6)$$

In (7) FR4 “Improve efficiency of logistics operations”, can be separated at level 2 in FR4.1 “Increase order accuracy”, FR4.2 “Increase on time delivery accuracy and reduce damage rate” and FR4.3 “Collect real-time information of logistics operation” deriving DP4.1 “Fleet management and alignment with standardization and rules”, DP4.2 “Delivery data analysis” and DP4.3 “Logistics operation monitoring”. The results show a decoupled design matrix.

$$\begin{Bmatrix} FR_{41} \\ FR_{42} \\ FR_{43} \end{Bmatrix} = \begin{bmatrix} x & o & o \\ x & x & o \\ o & o & x \end{bmatrix} \begin{Bmatrix} DP_{41} \\ DP_{42} \\ DP_{43} \end{Bmatrix} \quad (7)$$

In (8) FR 6 “Analyze and evaluate the risk of warehouse and transportation” we can separate at level 2 FR6.1 “Reduce damage rate in warehouse and transportation” and FR6.2 “Return products in case of damages” deriving DP6.1 “Monitoring and identification of damage rate in warehouse and transportation” and DP6.2 “Reverse logistics and alignment with standardization and rules”. The results show an uncoupled design.

$$\begin{Bmatrix} FR_{61} \\ FR_{62} \end{Bmatrix} = \begin{bmatrix} x & o \\ o & x \end{bmatrix} \begin{Bmatrix} DP_{61} \\ DP_{62} \end{Bmatrix} \quad (8)$$

Equation (9) shows the last requirement FR7 “Evaluate and improve service life cycle”, which can be separated at level 2 in FR7.1 “Evaluate the service life cycle” and FR7.2 “Re-design and improve service after evaluation” deriving DP7.1 “Fuzzy-AHP in LSPs lifecycle model based on CRM (history of complains and customer service)” and DP7.2 “Improved Service Model”. The results are uncoupled.

$$\begin{Bmatrix} FR_{71} \\ FR_{72} \end{Bmatrix} = \begin{bmatrix} x & o \\ o & x \end{bmatrix} \begin{Bmatrix} DP_{71} \\ DP_{72} \end{Bmatrix} \quad (9)$$

In this paper we applied I4.0 to improve the identified DPs for finding the best solution to achieve the target customer needs. In the following section 5 we will show the allocation of I4.0 technologies to the single DPs.

5 The Implementation of Industry 4.0

According to the decomposition of FR and DP, there are DP1: “Opportunity analysis for customer requirement”, DP2 “Validated strategies to increase customer satisfaction”, DP3 “Flexibility to support customer”, DP4 “Operations Management” DP5 “Monitoring of logistic costs and decision making rules” DP6 “Warehouse and Transportation Management” DP7 “Evaluation model and improvement process” and DP8 “End of Life Management (support decline stage and link historical data to DP1 to develop new service innovation)”. In this section, we look for suitable I4.0 technologies in the identified DPs for implementing information technology to satisfy requirements. In the following, the I4.0 technologies identified for each single DP are summarized:

DP1: Big data analytics to collect and analyse customer requirement data and marketing demand

DP2: Simulation and virtual technologies to create and test company strategies

DP3: IoT/IoS and real-time autonomous service to support customer

DP4: Real-time connectivity, track and trace technology and data integration

DP5: Horizontal/Vertical data integration to enable sophisticated business intelligence for cost controlling

DP6: IoT/IoS and Smart sensors

DP7: Big data analytics and Simulation

DP8: Product lifecycle management software

Figure 2 shows a graphical overview of DPs and applicable I4.0 technologies in the upper and lower level DPs.

6 Conclusion

In this paper, customer requirements can be responded and improved in the entire lifecycle of logistics service by using AD theory. Logistic Service requirements consist of three main phases and eight sub-criteria; (1) beginning of life (create and design), (2) middle of life (long-term relationship, operation and financial) and (3) end of life (risk management, evaluate and end of life decomposition). The functional requirements and design parameters were then further decomposed where necessary FR1, FR2, FR3, FR4 FR6 and FR7. Once the DPs were derived the research team tried to identify suitable Industry 4.0 technologies for each DP. The big data analytics, autonomous system, logistics automation system can be key role players to improve the whole lifecycle of logistics services.

7 Future Work

In future work, the proposed DPs and I4.0 technologies will be tested with three LSP companies to confirm their suitability for LSP's Lifecycle Model in Thailand. In addition, Best-Worst Method will be used to determine the significance of the criteria to validate the model.

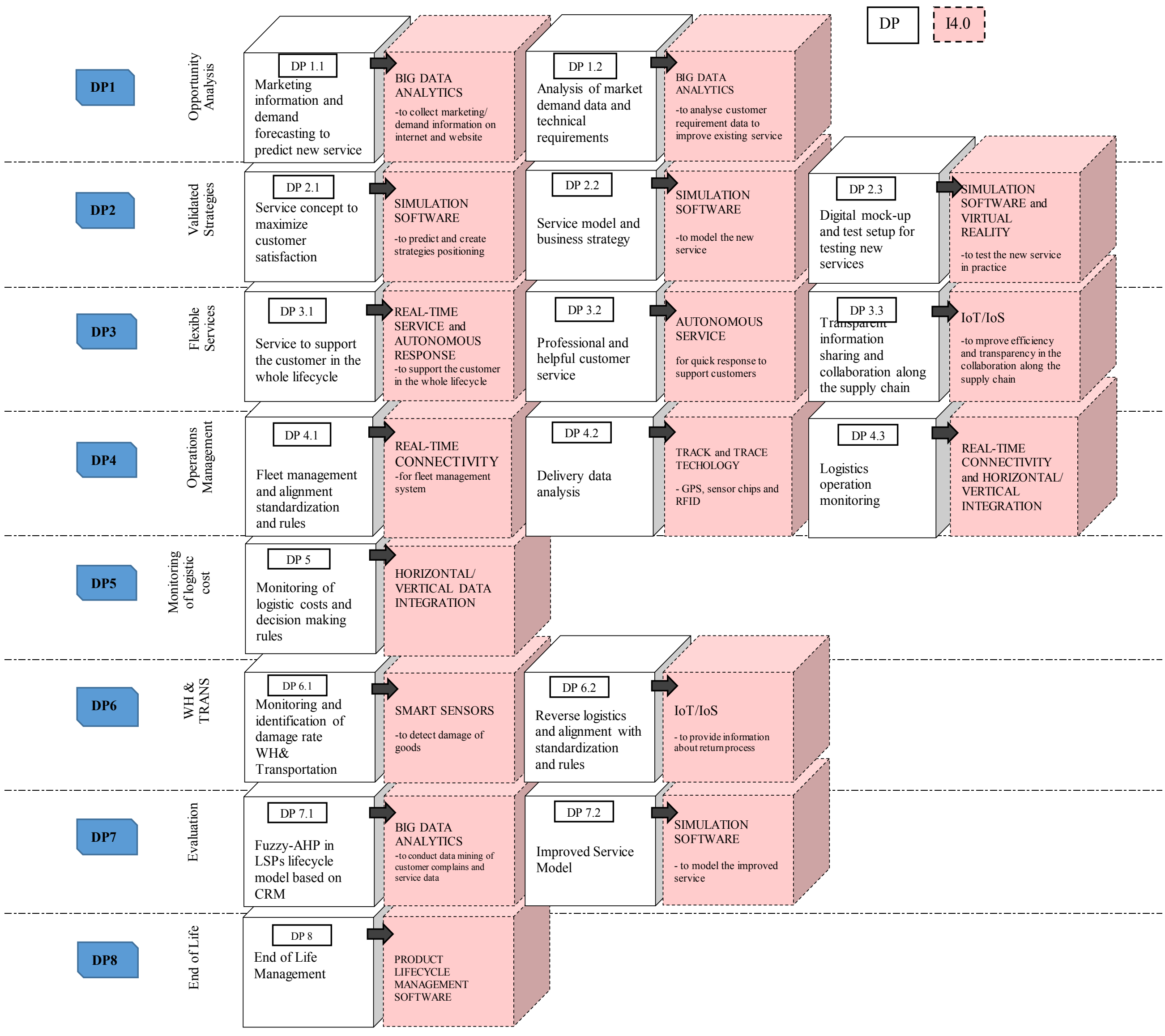

Fig. 2. Identified I4.0 technologies for the DPs.

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