Smart Innovation, Systems and Technologies 186

G. Jezic · J. Chen-Burger ·
M. Kusek · R. Sperka · Robert J. Howlett ·
Lakhmi C. Jain *Editors*

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Preface

This volume contains the proceedings of the 14th KES Conference on Agent and Multi-Agent Systems—Technologies and Applications (KES-AMSTA 2020) held as a virtual conference between June 17 and 19, 2020. The conference was organized by KES International, its focus group on agent and multi-agent systems, and University of Zagreb, Faculty of Electrical Engineering and Computing. The KES-AMSTA conference is a subseries of the KES conference series.

Following the success of previous KES Conferences on Agent and Multi-Agent Systems—Technologies and Applications, held in St. Julians, Gold Coast, Vilamoura, Puerto de la Cruz, Sorrento, Chania, Hue, Dubrovnik, Manchester, Gdynia, Uppsala, Incheon, and Wroclaw, the conference featured the usual keynote talks, presentations, and invited sessions closely aligned to its established themes.

KES-AMSTA is an international scientific conference for discussing and publishing innovative research in the field of agent and multi-agent systems and technologies applicable in the Digital and Knowledge Economy. The aim of the conference is to provide an internationally respected forum for both the research and industrial communities on their latest work on innovative technologies and applications that is potentially disruptive to industries. Current topics of research in the field include technologies in the area of decision making, big data analysis, cloud computing, Internet of Things (IoT), business informatics, artificial intelligence, social systems, health, transportation systems and smart environments, etc. Special attention is paid on the feature topics: agent communication and architectures, modeling and simulation of agents, agent negotiation and optimization, business informatics, intelligent agents, and multi-agent systems.

The conference attracted a substantial number of researchers and practitioners from all over the world who submitted their papers for main track covering the methodologies of agent and multi-agent systems applicable in the smart environments and knowledge economy and had four invited sessions on specific topics within the field. Submissions came from 16 countries. Each paper was peer reviewed by at least two members of the International Program Committee and International Reviewer Board. 33 papers were selected for presentation and publication in the volume of the KES-AMSTA 2020 proceedings.

The Program Committee defined the following main tracks: Software Agents in Smart Environment and Intelligent Agents and Cloud Computing. In addition to the main tracks of the conference, there were the following invited sessions: Agent-based Modeling and Simulation, Business Process Management, Agents and MAS applied to Well-being and Health, Business Informatics, and MAS in Transportation Systems.

Accepted and presented papers highlight new trends and challenges in agent and multi-agent research. We hope that these results will be of value to the research community working in the fields of artificial intelligence, collective computational intelligence, health, robotics, smart systems, and, in particular, agent and multi-agent systems, technologies, tools, and applications.

The Chairs' special thanks go to the following special session organizers: Dra. Maria del Rosario Baltazar Flores, Instituto Tecnologico de Leon, Mexico; Prof. Arnulfo Alanis Garza, Instituto Tecnológico de Tijuana, México; Prof. Hiroshi Takahashi, Keio University, Japan; Prof. Setsuya Kurahashi, University of Tsukuba, Tokyo, Japan; Prof. Takao Terano, Tokyo Institute of Technology, Japan; and Dr. Mahdi Zargayouna, IFSTTAR, France, for their excellent work.

Thanks are due to the Program Co-chairs, all Program and Reviewer Committee members and all the additional reviewers for their valuable efforts in the review process, which helped us to guarantee the highest quality of selected papers for the conference.

We cordially thank all authors for their valuable contributions and all of the other participants in this conference. The conference would not be possible without their support.

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Dr. Robert J. Howlett is the Executive Chair of KES International, a non-profit organization that facilitates knowledge transfer and the dissemination of research results in areas including intelligent systems, sustainability, and knowledge transfer. He is a Visiting Professor at Bournemouth University in the UK. His technical expertise is in the use of intelligent systems to solve industrial problems. He has been successful in applying artificial intelligence, machine learning, and related technologies to sustainability and renewable energy systems; condition monitoring, diagnostic tools and systems, and automotive electronics and engine management systems. His current research work is focused on the use of smart microgrids to achieve reduced energy costs and lower carbon emissions in areas such as housing and protected horticulture.

Dr. Lakhmi C. Jai, Ph.D., M.E., B.E. (Hons) Fellow (Engineers Australia) is with the University of Technology Sydney, Australia, and Liverpool Hope University, UK. Professor Jain serves the KES International for providing a professional community the opportunities for publications, knowledge exchange, cooperation, and teaming. Involving around 5,000 researchers drawn from universities and companies worldwide, KES facilitates international cooperation and generates synergy in teaching and research. KES regularly provides networking opportunities for professional community through one of the largest conferences of its kind in the area of KES.

Software Agents in Smart Environment

Revitalising and Validating the Novel Approach of xAOSF Framework Under Industry 4.0 in Comparison with Linear SC

Fareed Ud Din, David Paul, Joe Ryan, Frans Henskens, and Mark Wallis

Abstract Recent literature claims that Small to Medium Size Enterprises (SMEs), as compared to larger setups, may not be able to experience all the benefits of the fourth industrial revolution (Industry 4.0). In order to bridge this gap, the Agent Oriented Smart Factory (AOSF) framework provides a comprehensive supply chain architecture. AOSF framework does not only provide high-level enterprise integration guidelines but also recommends a thorough implementation in the area of warehousing by providing Agent Oriented Storage and Retrieval (AOSR) WMS system. This paper focuses on scenario-based comparison of the extended AOSF framework with a Linear SC model, to explain substantially improved performance efficiency especially in SME-oriented warehousing. These scenario-based experiments indicate that AOSR can yield 60–148% improvement in certain Key Performance Indicators (KPIs), i.e. number of products stored in racks, receiving area (RA) and expedition areas (EA), in comparison with standard WMS strategies.

1 Introduction

Supply Chain (SC) is a fundamental element that provides an organisation with process flow, regardless of the size of the organisation [1]. For SMEs, the importance of SC networks becomes more crucial as they rely solely on the tightly integrated subsystems and components to maintain business processes. The concept of Industry 4.0 [2] is no longer new. This initiative provides a flexible and advanced system which recommends a high-tech infrastructural shift, incorporating intelligent machines within the manufacturing Supply Chain (SC) and a high level of automated interaction in between the constituent components [3]. In order to build such a

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structure, additional infrastructural and operational cost is required [4]. However, for SMEs, implementing a low-cost, but effective solution has always been a preference [4]. Thus, a general SC framework for SMEs, based on Industry 4.0 standards, may help bridge this gap between Industry 4.0 and SMEs.

In order to bring SMEs many of the benefits of Industry 4.0, Agent Oriented Smart Factory (AOSF) framework [5] provides a moderate-level semi-autonomous system for SMEs to apply a comprehensive SC framework under the umbrella of Industry 4.0. The contribution of AOSF framework has been presented in a series of previous contributions including high-level SC-based AOSF architecture [5], its extended visualisation as a Cyber Physical System (CPS) [6], problem and domain definition to build the baseline model for its associated WMS strategy, Agent Oriented Storage and Retrieval (AOSR) [7], and *6-Feature strategy*, general work-flow of AOSR [8], a thorough performance validation of AOSR in comparison with standard WMS strategies [9] and Time Efficiency Validation of AOSR Planner Algorithm [10]. This paper focuses on scenario-based comparison of the AOSF recommended CPS-based SC model with the Linear SC model to explain how AOSF provides robust, proactive and systematic flow of operations. It also includes test case-based validation of AOSF's recommended AOSR-WMS strategy to affirm the validity of the overall system.

This article includes scenario-based test cases within the supply chain of a firm and relates them with two different possible cases of information exchange from the front-end customer side (CRM) and back-end supplier side (SCM). It also highlights the importance of the Business Process Re-engineering (BPR) strategy recommended by the AOSF framework. Some implementation results taken from the prototype developed in JADE [11] are also included to discuss the use of multiple warehousing and product placement/retrieval mechanisms provided by AOSR strategy, e.g. Zoning Logic, FIFO Logic and Pick from/Put to the Fewest Logic [12]. It also provides a comparison of the recommended AOSR hybrid product placement and retrieval strategy with standard WMS strategies. The discussion includes how the hybrid logic-based AOSR algorithm combines not only all the aforementioned logic schemes but also the 'Pick from/Put to the Nearest logic', in order to reduce the overall activity time within the shopfloor. It also includes validation of how the *6-Feature* strategy recommended by the AOSR system helps in bringing improvement and proactiveness within a warehouse.

2 Test Scenario and AOSF

Supply Chain (SC) is a philosophical boundary-less network within a business setup that prevails from the supplier side towards the customer side. Several different events could occur from any of the constituent parts of an SC network, e.g. supply chain management (SCM), enterprise central unit (ECU), logistical information system (LIS) or customer relationship management (CRM). This section addresses two

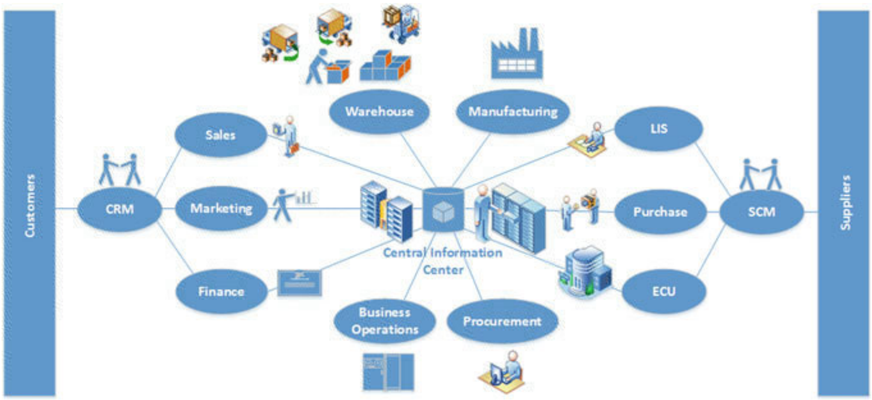


Fig. 1 A Linear view of supply chain network

possible approaches to create a comprehensive informational flow passing through different existing SC components:

1. *Create the bulk approach*, where the events are triggered from the supplier side and require the involvement of different units of the SC network. This case can be further segregated into two sub-scenarios, *Scenario 1A: Creating the bulk from inside* and *Scenario 1B: Creating the bulk from outside*.
2. *Break the bulk approach*, where the action is invoked from the customer side, creating a wave of initiation of different subcomponents of the supply chain up to the warehouse.

Both of the cases, with their sub-scenarios, are reflected by the linear representation of the SC network in Fig. 1, detailed below.

Scenario 1A: Creating the bulk from within the enterprise is a scenario where the manufacturing unit informs the central information centre about the completion of a particular batch, which is further updated to ECU. ECU collects details about the execution of production planning, process and disposition [13] related to particular finished or semi-finished (raw) products to be stored in the warehouse. After processing the data, ECU transforms it to decisive information and initiates a trigger, invoking a call for products to be stored with the details about dispositioning from the manufacturing side and delivery towards the warehouse side.

Scenario 1B: Creating the bulk from outside is a scenario where the products are to be delivered from suppliers to the firm. The SCM component is the primary interface that corresponds to the requirement of suppliers and deals with delivery details via LIS. SCM also performs operational planning, execution of procurement and completion with the purchase department, which are sub-operations of inter-departmental communication [14]. ECU collects data transmitted by SCM and LIS from the central information centre, and then, after processing that data, invokes a call to deliver the right batch to the warehouse with all the delivery details.

In the second approach of *Breaking the bulk*, the trigger is initiated from the front-end customer side. The CRM component is the main interface for dealing with the requirement of upcoming orders from the customer side. CRM coordinates with the department of sales and marketing and posts the data to the central information centre [14]. Then the information related to a particular shipment, in liaison with the sales department, is transmitted to the warehouse side. Section 3 highlights details of the test cases, for all the possible triggers initiated, in a routine day on an hourly basis in a distribution warehouse.

From the perspective of mapping Industry 4.0 standards to SMEs, three particular aspects, as mentioned below, are usually recommended through the use of RFID technologies, mobile user interfaces and auto/predictive control of inventory management [15]:

- Smart Logistics, providing connected units with predictive features;
- Smart Production, providing sensor-based environments within production plants; and
- Organisational/ Managerial model, providing comprehensive control to managerial staff.

AOSF framework takes all these recommendations into account and provides a comprehensive layout not only for organisation and modelling of an SC network but also for how it works in maintaining vertical, horizontal and end-to-end integration, which is an important factor to keep the whole system updated.

AOSF framework is based on a Cloud-based CPS architecture that provides the flexibility and scalability of adding Big Data features as needed in the future. At the moment, most SMEs are not considering data as a source of added value [16]. Also, the extensive use of collaborative robots is not exploited by SMEs yet and does not seem possible in the near future because of the high infrastructural cost involved with such automation [17]. Recalling the concepts of the tier-based AOSF framework and its extended view in Fig. 2, this architecture better caters to the cases discussed in a linear SC structure as it provides a proper integration mechanism though an Intra-Enterprise Wide Network (IWN), which also provides three-dimensional enterprise integration (as discussed in our previous work [6]). The traditional SC elements, such as the SCM, CRM, plant side, business operation side and warehouse side, with all the smart devices, are part of the Smart Connection Layer, which further provides connectivity to ECU. ECU in AOSF architecture is considered a focal point which serves as a middle layer sensing the data and transforming it into decisive information. All the backup and monitoring facilities are set up at the Cyber Cognition Layer which provides overall cognitive abilities to the system. Such a three-dimensional structure of the AOSF framework also helps in maintaining a proper backup at the cloud layer, while keeping all the constituent elements updated concurrently. Agent orientation also gives the AOSF framework a further benefit of flexibility where agents interact with each other for a particular resource constraint and themselves are helped by utilising their own local inference engine and belief sets. AOSF framework recommends standard classification of reflex agents, utility-based agents and

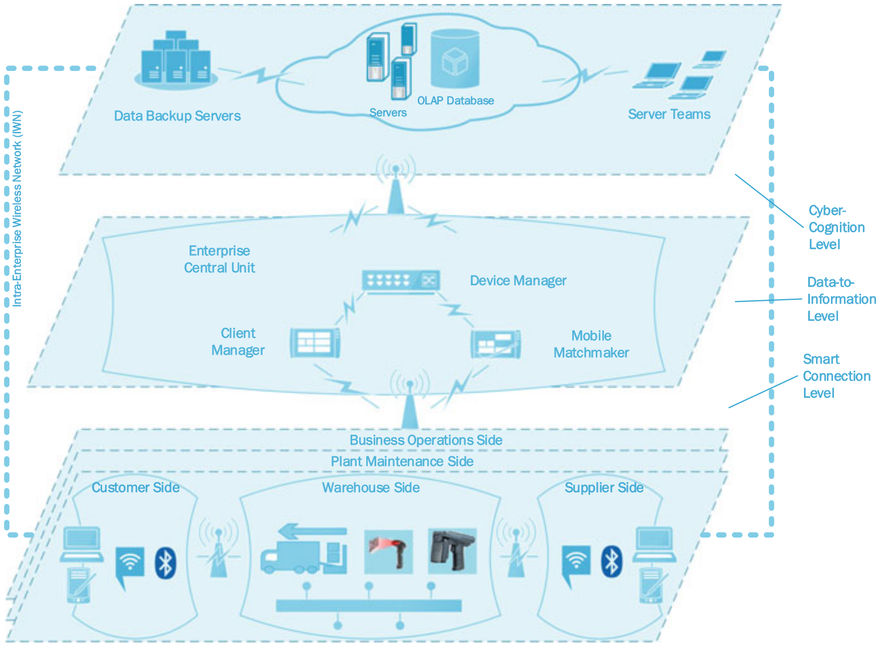


Fig. 2 Extended view of AOSF framework

goal-based agents, i.e. Smart Device Agent (SDAs), User Side Agent (UAs) and Mediator Agents (MAs), in order to provide decentralised decision-making, thus making operation seamless and robust.

3 Dataset and Test Cases

In order to provide a solution to improve warehouse management in SMEs, the AOSF framework recommends its associated AOSR-WMS mechanism with its *6-Feature* strategy [8], which is prototyped in JADE [11], as detailed in [6]. For a thorough validation of this system, the data used to evaluate the test cases, for different categories of products in different scenarios, is represented in Tables 1 and 2. All the data categorisation of the products applied to the AOSF framework and its associated AOSR algorithm are taken as a test/example case, which can be modified as per business need. The details of different classes and categorisation of products in these test cases are extracted from the online source provided by DGI Global [18] and Eurosped [19] warehousing and logistics companies. In order to build a comprehensive dataset that includes maximum variation and can be considered as representative for large-scale applicability, several different features are included, such as product classes, their characteristics, SKUs and different situations of product delivery and shipment. The data used to validate this system is stored categorically within the highlighted constraints as detailed in Tables 1 and 2. This comprehensive dataset does not only include one type of product category, it consists of the information of several characteristics of products, e.g. SKUs, quantity and products classes, from several different industrial sectors, e.g. electronics industry, medical industry, textile firms, paint and glass industry. Table 1 takes 32 different triggers into account and categorises them into the aforementioned generic scenarios: *Scenario 1A (creating*

Table 1 The dataset used for hourly *Creating/Breaking the Bulk* Test Cases

Tr. #	Case	Initiator	Hours	Product ID	Quantity
1	1A	ECU	1st	P-9001	17
2	1A			P-9002	13
3	1B			k-9804	23
4	1A			K-2098	27
5	1B		2nd	L-3092	17
6	1B			K-9803	33
7	1A			F-9210	47
8	1A			L-2801	33
9	1A		3rd	F-2830	23
10	1B			C-3921	27
11	1B			R-3392	67
12	1B			R-1292	43
13	1B		4th	P-8372	53
14	1A			K-3269	27
15	1B			R-3390	67
16	2	CRM		P-9001	5
17	2		5th	P-9002	25
18	2			k-9804	33
19	2			K-2098	67
20	2			L-3092	53
21	2		6th	K-9803	23
22	2			F-9210	37
23	2			L-2801	73
24	2			F-2830	47
25	2		7th	C-3921	33
26	2			R-3392	27
27	2			R-1292	43
28	2			P-8372	17
29	2		8th	K-3269	23
30	2			R-3390	17
31	2			P-9001	27
32	2			P-9002	13

Table 2 Categorisation/classification of products with respect to characteristics

Sr. no.	Product ID	Product name	Characteristics			
			SKU	Hazard	Fast	Finished
1	P-9001	Small Electronics	E/B	✗	✓	✓
2	M-1001	Medical Supplies	B/C	✓	✓	✓
3	P-9002	Household/Hygiene	B/C	✗	✓	✓
4	K-9804	Large Electrical App.	B/C	✗	✗	✓
5	K-2098	Textile Items	B/C	✓	✗	✓
6	L-3092	Crops Prot. Materials	B/C	✓	✗	✗
7	K-9803	Glass Bars	B/C	✓	✓	✗
8	F-9210	Paints/Chemicals	B/C	✗	✗	✗
9	L-2801	Oils/Lubricants	B/C	✗	✓	✗
10	F-2830	Chalking Material	C/P	✗	✗	✓
11	C-3921	Spare Parts	C/P	✗	✓	✓
12	R-3392	Stationary/Paper Logs	C/P	✗	✗	✗
13	R-1292	Industrial Goods	C/P	✗	✓	✗
14	P-8372	Dyes Pallets	C/P	✓	✗	✓
15	K-3269	Large Mechanical Parts	C/P	✓	✓	✓
16	R-3390	Pest Control Powder	C/P	✓	✗	✗
17	P-9003	Household Equipment	C/P	✓	✓	✗
18	R-3292	Alkaline Substances	Br	✓	✓	✓
19	K-4940	Large Liquid Containers	Cyl	✓	✓	✓
20	K-9805	Long Glass Screens	SP	✓	✓	✓

the bulk from inside), Scenario 1B (creating the bulk from outside) and Scenario 2 (breaking the bulk) (in column 2), with their initiator SC-unit in column 3. The first 15 cases are related to the case *Creating the Bulk*, both from inside and outside, and the others reflect the scenario of *Breaking the Bulk*. This dataset is segregated into 8 divisions (as represented in column 4) with respect to working hours and details of shipment and delivery within the warehouse for each hour. For the sake of clarity and uniformity only 4 triggers per hour are considered; there are usually 0–6 data transactions per hour depending upon the size of an enterprise [18, 19], so this is realistic. Every product is assigned a unique *Product Id* (as represented in column 4), which encapsulates all the details related to the characteristics of a particular product. In column 6, the quantity represented is a random number (in the range

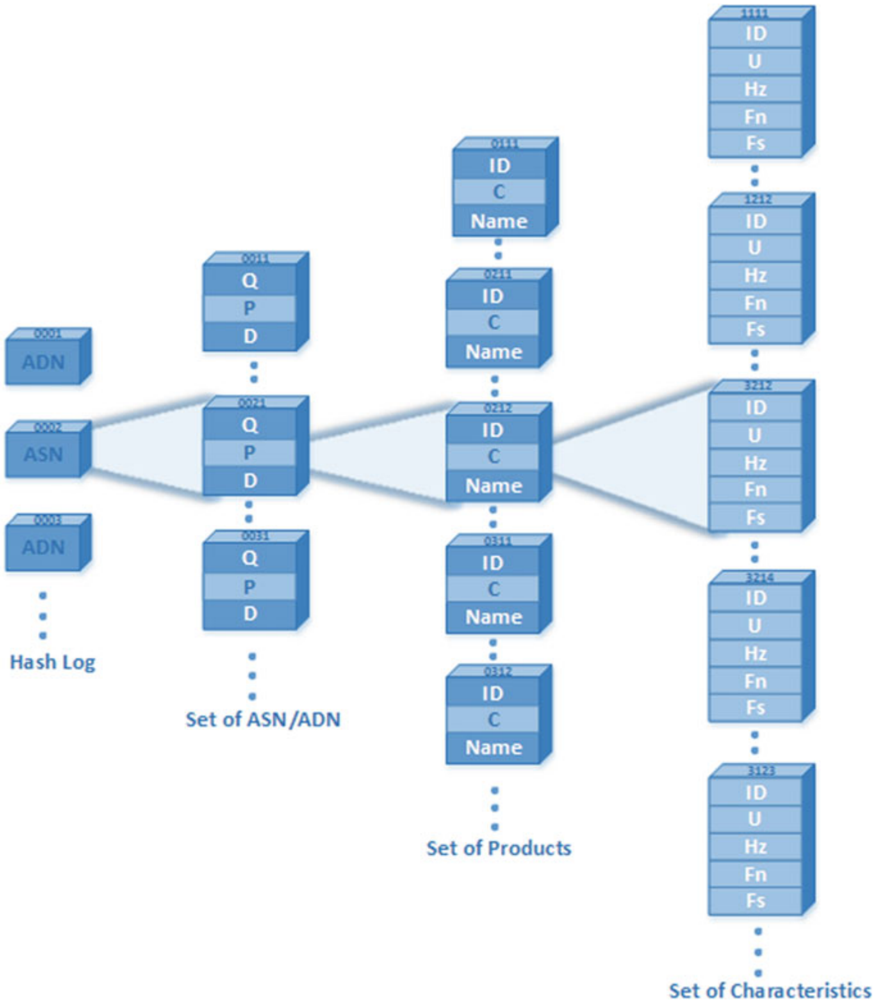


Fig. 3 4-level storage of knowledge structures

1–100, as per available industrial data) of products being requested by any of the SC components from the network, e.g. ECU or CRM, which corresponds to a particular delivery or shipment, respectively (further examination of these random values are discussed later in this article).

This dataset comes with combinations of multiple possibilities such as delivery and shipment instances with varying product details (based on product category, characteristics, SKU, quantity and due date); hence, it is stored in four levels of data abstraction (4-level knowledge structures). Figure 3 explains the details of these knowledge structures utilised by the AOSF framework. These main knowledge structures are contiguous and continuous logs of shipment and delivery details, where each log is related to a particular case. The AOSF framework stores these information logs as *HashMaps*, and refers to them as *hash logs* as reflected in Fig. 3. In an instance of *hash log storage*, there could be *n* possible Advance Shipment and Delivery Notices (ASN/ADN). In all cases, the origin of the details is the product that needs to be dispositioned in a particular Stock Keeping Unit (SKU). For every product, the uniquely identifiable *Product ID* corresponds to a specific category which could be hazardous products, unfinished products or brittle/fragile items. Products could also be distinguished based on their packing units (SKUs) such as Each per Box (E/B), Boxes per Case (B/C), Cases per Pallet (C/P), Barrels, (Br), Cylinders (Cyl) or Single Pallets (SP). The categorisation of products applied to the AOSF framework and its associated AOSR algorithm are highlighted in the dataset represented in Table 2. As highlighted above this data is taken as a test/example case, which can be modified as per business need. To apply the dataset to AOSF and AOSR strategy, the products are classified as per four parameters: their SKU, Hazard category, Movement (slow or fast) and Finished or Unfinished. In order to provide comprehensive testing, six different types of SKUs (E/B, B/C, C/P, Br, Cyl, SP) and six different types of characteristics (binary values of hazard, fast and finished classification) are considered with 20 different classes/categories of products. The AOSF framework and AOSR strategy, both provide the flexibility to accommodate such variability of products. The details about how AOSR, with its *6-Feature* strategy, provides the scalability for the same or different categorisation of products are included in our previous work [8].

4 Results and Discussion

All the aforementioned test cases are applied to the AOSF and AOSR strategy in comparison with a standard WMS strategy (explained in detail in our previous work [8]). In order to bring clarity in results and to provide better recommendations, this research is constrained to three very important key performance indicators (KPIs):

1. number of products stored in racks;
2. number of products kept at receiving area (RA); and
3. the number of products placed in expedition areas (EA).

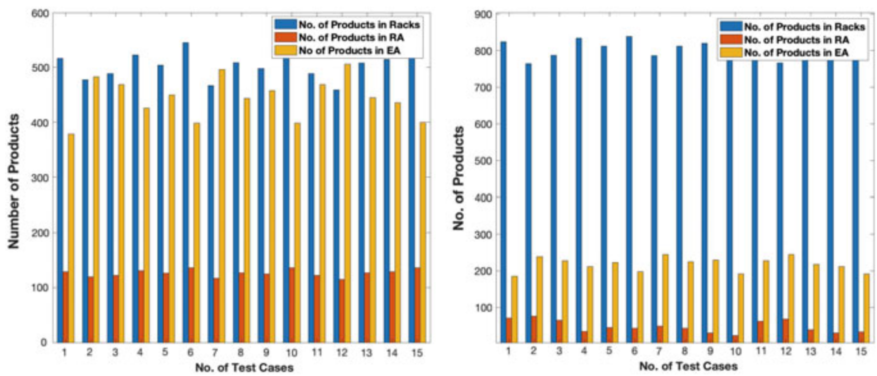
Our work on visualising AOSF as a CPS [6] includes the validation of AOSF/AOSR strategy with specific case-based test cases. In this article we have included multiple random test cases applied to AOSR and Linear SC-based standard WMS strategy to reflect the inclination of both with respect to the aforementioned three performance metrics.

Low performance in managing these three parameters results in basic WMS issues such as receiving area overloading, demarcation lines vanishing, manual re-slotting and wandering/lost items [20]. The literature has often mentioned persisting SC and

WMS issues, and the main reasons behind such problems are mostly the unmanaged receiving and expedition areas [21] and unmanaged storage capacity [22]. A higher number of products within the racks is usually considered as a performance metric for efficiency in warehousing [23].

The general applicability of a system can be validated by analysing its performance over a wide range of data. As explained in the previous section, a diverse case study with a broad scope helps indicate the performance efficiency of AOSF and AOSR strategy. In order to confirm its validity over a wide range of possible scenarios, this section describes several tests applied to the AOSF with the AOSR strategy in comparison with the standard approach. In contrast to the standard WMS strategy [22, 24], which provides centralised management of tasks such as tracking location and level of products in the racks using a single logic, AOSR utilises its hybrid logic-based strategy [8] as per the products' characteristics to generate the placement plan. The dataset described in Sect. 3 has been modified with different random values for the quantity, to help ensure this generic case study is more widely applicable.

Figure 4 represents the detail of the first 15 (out of 30) test cases applied to the subject strategies. For clearer visualisation, only the first 15 cases are displayed in the graph. A closer look at Fig. 4 demonstrates that there is a similar trend for a wider range of data as compared to specific case-based validation performed in our previous work [6]. Figure 4 demonstrates the number of products in all three areas (Racks, EA and RA). The products in racks are represented by blue bars, products in EA with orange and the products in RA are represented with red bars. The standard WMS strategy tends to balance between all the three aforementioned KPIs (number of products in racks, RA and EA), while for the AOSF recommended strategy, the main priority is to manage the maximum number of products in the racks. Figure 4a, on the left, shows that, out of 1080 products, at most around half of them are in racks and, from the remaining products, a major proportion are stored in EA. Furthermore, approximately one-quarter of the total products seem to be stuck in the receiving area.



(a) Standard WMS Strategy (b) AOSF with AOSR Strategy

Fig. 4 Performance results with random data

This trend can be observed in all test cases. As previously stated, such a situation leads towards the problems of mismanagement onto the shopfloor and causes the concerns of the unmatched stock count, missing or wandering items and extended lead time of order processing.

On the other side, in Fig. 4b the major proportion of the total products, almost 80%, are maintained in the racks, in almost all test cases. The AOSF/AOSR strategy is designed to prioritise the placement of as many products in the racks as possible by utilising its slotting and re-slotting strategy to make more space available within the racks for upcoming products (as detailed in [8]). This is why it succeeds in maintaining a very low number of products in RA: around 40–50 products as compared to 100–150 products when using the standard approach. Also, there is a good difference in the products detained in EA when using AOSF, with around 180–210 stored in EA with AOSF as compared to 390–440 with the standard approach.

Figure 5 represents the average results of the 30 test cases used in this section. The standard WMS strategy, as already discussed in the detailed data value graph in Fig. 4, tends to maintain the balance between the number of products in all the three sections of shopfloor: racks, EA and RA. It is represented by the purple-shaded region in the graph. On average 507 products are in racks, 444 are in EA and 127 are in RA. For AOSF, the focus is to maintain the products in racks, as can be seen by the deflection of the graph towards the corner of 'Rack'. That means there are more data points towards the 'Rack' corner as compared to the others. On average 814 products are stored in racks, 215 are placed in EA temporarily and only 52 are at RA. These numbers provide quite a fair improvement in efficiency as presented by Fig. 6.

Figure 6 demonstrates the performance improvement over the average of the 30 random test cases. The blue bars represent products in racks, orange bars show the number of products in EA and red bars represent the products in RA. The number of products maintained in racks by utilising the AOSF recommended strategy brings a 60% increase in the number of products stored in racks, a 107% decrease in the number of products in EA and a 148% decrease of items in RA. These results are

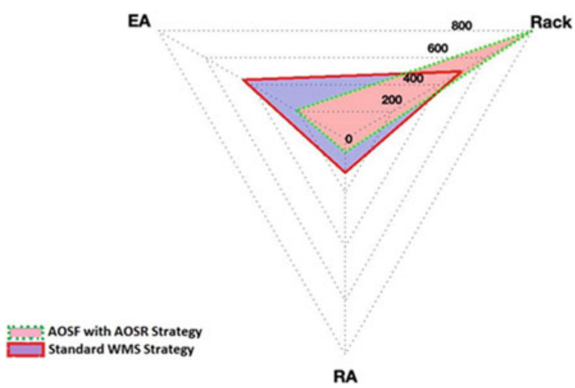


Fig. 5 Performance inclination with random data

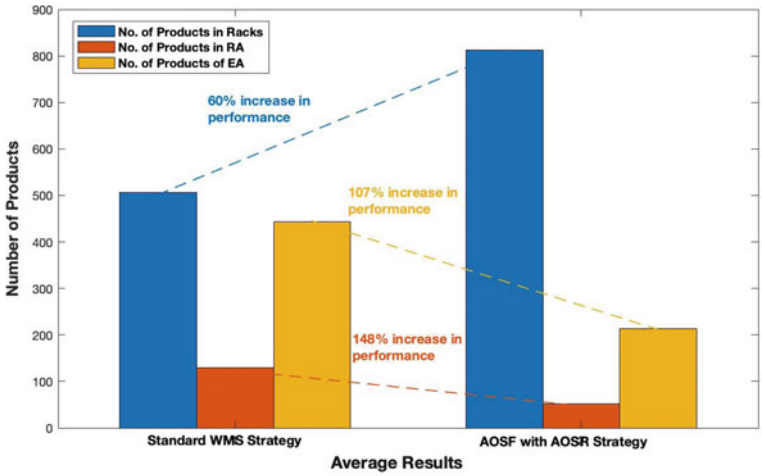


Fig. 6 Improved efficiency with AOSR/AOSR strategy

very close to those obtained with the specific case-based test cases presented in [6], indicating that the case study presented and multiple random datasets are good representation of typical results. The consistency of performance while utilising AOSF recommended strategy speaks about its validity and broader applicability.

5 Conclusion and Future Work

In this article, scenario-based comparison of xAOSF's three-tier architecture with the Linear SC model is discussed, to explain how AOSF framework provides seamless flow of information with robustness. The test cases analysed the products stored in racks, in EA and in RA, each with respect to two different system states: *State 0* (without conflicts) and *State 1* (with possible conflicts). The time efficiency of the AOSR strategy in relation to the standard approaches is also discussed in our other work [10]. The results are extracted from different test cases applied to validate the AOSF and its recommended AOSR-WMS strategy in comparison with standard WMS strategies. The successful and positive results, from all the scenarios and test cases, highlight the overall performance efficiency of the AOSR algorithm in association with its parent AOSF framework.

The AOSR-WMS strategy is one part of the implementation of the AOSF framework; in future there are still other open areas to work, e.g. plant maintenance, transportation and other SC operational activities. Addition of other state of the art features, i.e. IoT and Big Data may also provide this system with more cognitive abilities in order to provide intelligence, based on past data trends. Although most SMEs do not currently consider data as a source of added value [16], it could be a valuable addition in the future. The AOSF framework presents CPS-based provision for storing and maintaining historical data, for the purpose of predicting future trends and providing flexibility to incorporate data analytics in future. The ideas contributed by Voss et al. in [25] related to incorporating Big Data analytics in logistics can also be a part of this system to enhance it for future purposes. Similarly, handling tasks with the same priority can also be a value addition to the general contribution of AOSF framework.

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