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Proposed Order Management System (OMS) for GAZI Communications

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***Abstract*:** This study aims to propose an Order Management System (OMS) to automate the entire sales order management process for GAZI Communications, a system integrator company in Bangladesh. The study developed a proposal for a system based on the structure of a Transaction processing system (TPS). The proposed system has experimented with the data obtained from 41 employees of the respective sales department of GAZI Communications. Microsoft Excel was employed to analyze the data for assessing the requirement of the organization's requirement. There are a couple of issues that are found in the existing sales process including difficulties in on-site customer meetings, delayed order processing, difficulties in order management, complexities in managing multiple supplier management, errors in the shipping product, lack of visualization, and tracking the order. The result also identified 7 non-functional features- a) security, b) presentation, c) capacity, d) availability, e) recoverability, f) Usability, and g) documentation. Also, the study uncovered 9 functional requirements for the proposed system- a) centralized order management, b) customer management, c) quotation and order placing, d) payment gateways, e) reconciling the order, f) inventory management, g) fulfillment points integration, h) shipping services integration, and I) collaboration. The findings have a notable empirical implication for business organizations that do not have an automated OMS.

***Keywords*:** GAZI communications, OMS, order management system, OMS based GAZI, OMS system.

1. Introduction

In recent times the sales process of business organizations is increasingly becoming competitive and complex in a rapidly changing business environment. A dramatic shift has also been found in customer expectations and product demand.

There is no way to survive without delivering a seamless customer experience in a cost-effective, easy, fast, and efficient manner with proper sales process visualization. This is where an order management system can assist the organization by automating the sales process [1–3]. This is how an OMS can align customer expectations and current market demands. GAZI Communications, a system integrator company in Bangladesh, has been selected as a case study [4, 5].

The selected organization has been facing a lot of problems in its current manual sales system -a) difficulties in on-site customer meetings, b) delayed order processing, c) difficulties in order management, d) complexities in managing multiple supplier management, e) error in the shipping product and f) lack of visualization and tracking the order. The goals of this study are a) to propose an order management system (OMS) solution for automating the sales process, b) to find key drawbacks in the existing system, and c) to find the functional and non-functional features requirements to overcome those problems.

The rest of this paper is organized as follows. Section 2 reviews literature studies. Section 3 shows the methodology of this paper. Results and Discussion parts are provided in Section 4 and Section 5, respectively. Finally, the conclusion section is described in Section 6.

2. Literature review

Transaction processing explains the task conducted by a computer when an external stimulus especially data is introduced into the frame. Transactions, however, consist of a collation of functional closely related data elements that can combine with either explicit or context application signals.

The transaction method is commonly used globally based on the processing system that the system uses. Different processes are used for transactions and the mechanism has different functions to execute the transaction. As part of this value proposition, a business transaction processing system is a system that assists an organization in the execution of its business transactions [6–9]. TPS is commonly used to keep track of everyday business transactions by an organization's administrators and first-line managers [10]. A Data Driver Transaction Processing System (DD-TPS) was developed for the restaurant with payroll management, integrated POS, inventory control modules, and credit cards. To control the business process within an enterprise it's evident there is a need to acquire an information system [11–13]. Hence the development of networking software enables a unique approach to the development of this new system. Hence transactions can be categorized into two types: inquiry and file maintenance. The inquiry transactions are mostly requested transactions commonly requested for and serviced. This can produce a specific report produced in batches and the order management service falls into this category [14, 15].

[13] presented a classification of models applied in TPSs such as the online, batch, virtual terminal, groupware, client-server, workflow, and interactive voice response. The factors for evaluating the ergonomics of the models were built. The

Table 1. Team Formation and status

Group Member Name	Development Role	Development Task	Description of the development task	Status
Mudashiru Lateef	CEO	Team Formation and Management	Form, direct and manage the development team. Make available the needed materials for the task	Completed
Faizilah Ab Halim	Business Analyst	Requirements gathering	Acquire what features users would like to be included in the system	Completed
Nor Syida Rusly	Data Modeler	Data Definition/ Modeling	Define what types of data to be used in the system	Completed
Gayathiri A/P Vijayan	System Architect	System Flow Design	Define in a flow chart how a user would use the system	Completed
Al Mamun Md Habib	Project Manager	Components integrations	Component integration, Step by step, User Manual	Completed

first main classification of TPS was assigned as the - operator system, one-operator system, and the groupware system [16]. The first set of classifications was further sub-classified based on computer system operational characteristics which include similarities in the computer technology applied by the TPSs such as the sensitivity of the systems to the operator's needs. The authors explained the characteristics of TPSs and examined all the various categories and sub-categories of the TPSs. These categories and sub-categories are sown in Figure 2 as adopted from the study [17]. The authors concluded that the trend in the use of personal computer systems and networks as terminals have provided novel alternatives for the structuring of TPSs. One of the supply chain management systems is the order management process, which has an important role in the company's consumer satisfaction and benefit. Therefore, the organization should re-engineer its business process to compete with other companies or competitors [18–20].

Order Management System has been used in the past conventional customer interaction approaches, mostly being part of call center applications and ERP systems. These early order management systems included a basic set of features that allowed users to produce, change, and return orders. Besides that, deliveries were delivered from the local warehouse and no information on stock levels or order status was provided in real-time. The ideal complement to a traditional ERP system is an order management system. The order management system functions as the central interface between, on the one hand, a rapidly evolving marketplace with complex, customer-oriented applications and, on the other hand, existing ERP-based business processes when both are combined [18, 19, 21]. One such solution is an order management system, as it provides a connection between internal IT systems built and business processes on the one side [22].

An End-to-End Customer Order Management System (E2E COMS) was proposed by [23] with emphasis placed on the effective use of staff and mutual resources to help real-time order management and mitigate the risk of handling complex missions. The proposed framework consists of three integral tools: the Order Fulfillment Progress Prediction Tool (OFPPT) to forecast the anticipated remaining order completion period, taking into account inventory and resource ability constraints, the risk mitigation (RMT) tool to evaluate the risk of missing an order shipment and the Order Prioritization Tool (OPT) used to analyze and prioritize customer orders for each business channel. This led to the development of a real-time dashboard to visualize customers' orders, the system can be used for prompt decision-making and shipping capacity management.

3. Methodology

3.1 Team Formation & Management

The team was formed based on our level of experience to get out the best in each individual. The decision-making roles the team was classified into were CEO, Business analyst, Data Modeler, System Architect, and then project manager. In Figure 1, the clear organizational chart shows the team structure. The business analyst, system architect, and data modeler all report to the project manager that now reports to the CEO. In Figure 1 the team management structure shows how the team is structured and how the team worked throughout the research.

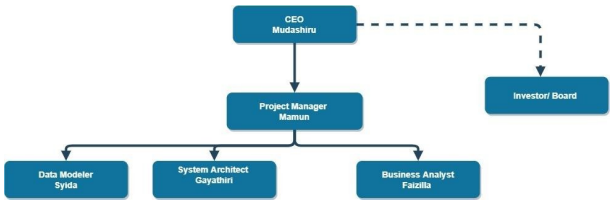

Figure 1. Team management structure.

3.2 Requirements Gathering

In this study, a quantitative method has been used to analyze the user's business problem and the requirement for proposing an Order Management System (OMS). Gazi Communications, Bangladesh has been selected as the target place for data collection because of easy volunteering and access by the researcher. The sample of the current study includes employees from several departments including Business Development, Information Technology, and Information Systems. Self-administered questionnaires were distributed to a total

of 60 respondents over a week in December 2020. The questionnaire was prepared and distributed in English. Because English is widely used in most corporate organizations. The questionnaire has been designed in Google Forms a YES/NO scale was used for answering the questions. The font and color issues were taken into consideration as it has an impact on the respondent. The question was kept short and right in order so that respondents can easily understand and respond. The question wording has been chosen so that it does not direct the respondents in any direction. The questionnaires were developed and divided into three parts- a) problem statement, b) non-functional requirement for the proposed OMS, and c) functional requirement for the proposed OMS. The questionnaire contains a total of 55 questions. Microsoft Excel and Google Spreadsheets were used for analyzing the collected data. After analyzing the data, the features will be transformed into requirements by using the method described in Figure 2.

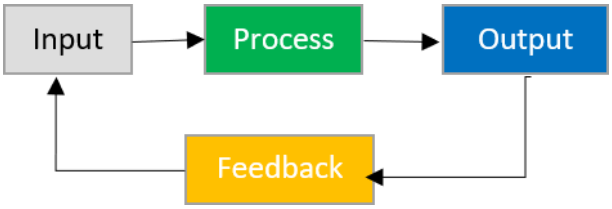

Figure 2. The input, process, and output procedure.

The following Input is:

- Customer Registration
- Execute online agreement
- Choose the drop point for the product
- Create an order

The following Process is:

- Calculation cost and time
- Updating database
- Retrieving Information
- Generating Invoice and Bill
- Checking on the warehouse stock Purchase Order generation to supplier

The following Output is:

- Generating proof of delivery
- Customer Quotation Queries
- Customer post Order Queries
- Log of all transaction
- Dispatch invoice and bills

3.3 Data Definition

The below data model exhibits data in an organized way which enables the system to store and retrieve the data in a relational database system. The entity relationship has also been shown in the data model. There are a few types of entities shown in Figure 3.

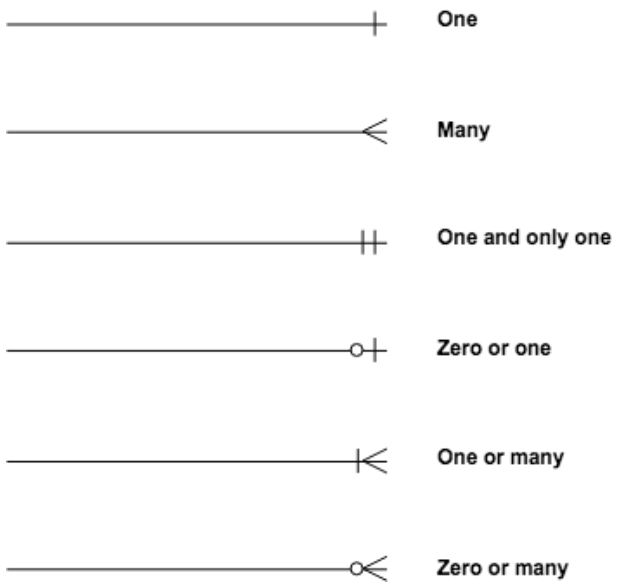

Figure 3. The data model.

3.4 Modeling

The order management system (OMS) was developed on the company's website. This system helps customers and business developers to ease the complex process into a smoother one. Firstly, customers need to log in and input all their needed information. The business developer also must log in to the system to do the sales inquiry. For example, customers log in to the system, add in all their company information, and ask for sales inquiries with the business developer. The automated system will send an email automatically to the business developer and therefore BD can get all the information from the customer. In the case of conducting the virtual meeting through the system, BD still has to log in to the system. Therefore, both the customer and business developer must log in to the system. Once the sales and information are enquired, the customer and business developer can decide to have a virtual meeting. Even though it's a single process yet, the virtual meeting can happen in several sessions which is more than once through the system, and the system helps to record the meeting, and it depends on customer and business developer discussion. According to the discussion, the business developer understands the customer's needs and requirements; a price quotation will be created through the system and will receive by the customer through email. Customers will undergo the negotiation process with the business developer by email or in a system update and the final price submission will be provided by the business developer. There will be two processes deciding on a deal through the system after the final price submission, which is either deal accepted or deal rejected. If the deal is accepted, the customer needs

to confirm the quotation, and agreement, and place the order. On the other hand, if the deal is rejected then the system will update and send either notification or email to the business developer to check on that [24]. BD will contact the customer and if the customer is not satisfied then the order is canceled in the system. After the order and payment are placed, then the systems request an order from the warehouse. The available stock will be updated in the system and if the product is available the system will automatically allocate the order quantity and the working order will be prepared by customer service. Customer service will receive delivery orders and customer information to make sure of shipping arrangements. The order management system will generate an invoice which will be sent to the billing department and the customer. Once the invoice is confirmed, the system will produce gate passes for security checking purposes which have all the information from date, time, quantity, type of product, delivery order, and finally ship the goods safely to the customer. On the other side, if the product is not available then the BD will create PO (purchase order to the supplier, and payment is transferred to the supplier. Once the product is delivered to the warehouse, the system will update the number of stocks and will send the product to receive a note to the business developer through email. Then, BD will arrange the whole process from order allocation to shipping through the order management system. Figure 4 shows the system flow design. Figure 5 provides an OMS data flow chart.

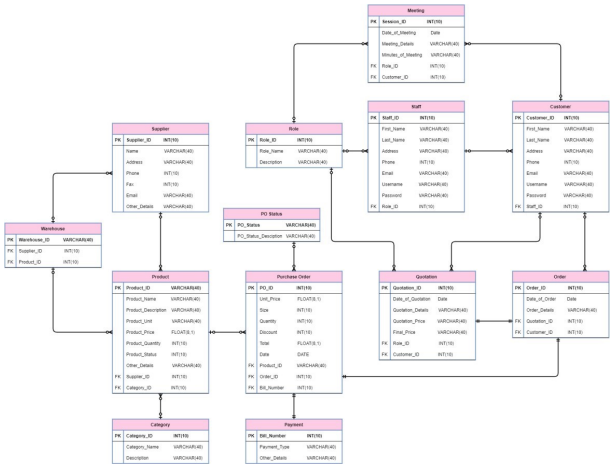

Figure 4. System Flow Design.

3.5 Components Integration

Figure 6 showed that the proposed system has been divided into 3 parts- a) web login, b) interfacing, and c) feature integration. The customer and business developer must log in to the OMS through the company website. Admin users can log in to the OMS from the internal network directly by employee ID and a single sign-on password provided by their organization. User registration is a must for every new customer by providing name, address, email, contact number, username, and password. However, the business developer does not need a user registration process and logs in to the system through the website by using their employee ID and

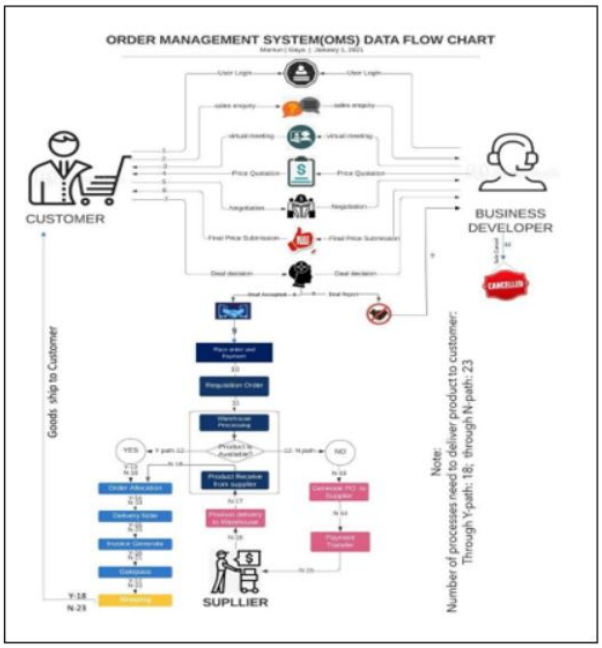

Figure 5. OMS Data flow chart.

single sign-on password provided by their organization. To complete a sales cycle, the OMS must interface with other related existing systems including IMS, IAS, payment gateway, and an email server. The OMS should integrate multiple features for various purposes for customer and business developers including inquiry, price request, negotiation, deal decision, order tracking, quotation, delivery tracking, and so on.

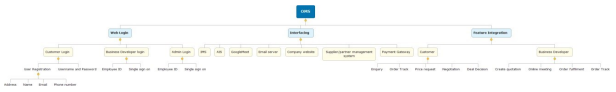

Figure 6. Step by step User Manual.

3.5.1 Customer Login Dashboard:

- Step-1: Go to URL “ www.gazicomm.com". Click “Login" in the right corner.
- Step-2: For the new user, click on the “create an account" button.
- Step-3: Fill-up the user registration form along with username, password, delivery address, cell number, etc. and click on “signup".
- Step-4: An email automatically sends to your mailbox for confirmation. And click on it. Your user will be activated.
- Step-5: Provide an email address and password for login into the OMS.
- Step-6: After login, the customer will get the below buttons for multiple sales purposes.

3.5.2 Business Developer Login Dashboard:

- Step-7: Go to URL " www.gazicomm.com". Click "Login" in the right corner of the homepage.
- Step-8: The business Developer will log in using the employee ID provided by the organization. The same organization password will be used as a single sign-on procedure.
- Step-9: After login, the Business developer also gets a lot of buttons to fulfill the sales process.

4. Results

The questionnaire for data collection was divided into three parts-a.) focused on identifying problems faced by the business organization, b.) focused to know the non-functional features, and c.) focused to recognize the functional features.

A total of 36 respondents submitted their opinions regarding the problems they have been facing in their sales process. The questionnaire comprised 10 different problem questions analyzed as shown in Table 2. It suggested that around 75% of respondents agreed that the manual process is not good for business. Only 25% of the respondents were in favor of the manual process. A response based on customer meetings with over 83% of respondents faced the problem with onsite-customer meetings. Only 17% of users didn't feel any difficulties regarding the onsite meeting. That around 80% of respondents thought that order fulfillment was often delayed, and only 20% opposed that. It that 83% of people surveyed faced difficulties in order managing. 17% of the respondents didn't agree with that. It indicated that around 80% of employees feel the complexity to manage multiple suppliers manually. Only 20% didn't agree with it. Over 83% of users faced difficulties in the order tracking. 72% of interviewees thought that sometimes errors happened in order shipping. The fact that 80% of users thought that instruction manual order processing makes delivery time slower. That 80% of the respondents were thinking they don't know the sales process from start to end. Figure 15 also exhibited that 80% of respondents indicated that they don't have any visibility and tracking feature in their current sales process. Finally, the data analysis comes up with the problems faced by the business organization as follows.

- A manual sales management process is a problem for businesses.
- difficulties found in onsite-customer-meeting
- facing delay in order processing
- found difficulties to manage orders
- complexity for fulfilling the orders from multiple suppliers
- facing hurdle to tracking orders
- errors like shipping the wrong product or to a wrong address

Table 2. Results of a questionnaire for data collection

Questions	Yes	No
Do you think a manual sales management process is good for business?	0	27%
Do you think any difficulties with onsite customer meetings?	30%	6%
Do you face delays in order processing?	29%	7%
Do you feel the complexity of fulfilling the order from multiple suppliers?	29%	7%
Do you face hurdles to track orders?	30%	6%
Do you make any errors like shipping the Wong product or to the wrong address?	26%	10%
Do you think order processing time takes days causing slower delivery times?	29%	7%
Do you understand in detail the current sale processing in your organization?		
Do you have any visibility or reporting into current sales processes?	7%	29%

- order processing time takes days causing slower delivery times
- No clear view in detail of the current sale processing in the organization
- No visibility or reporting into current sales processes

Figure 7 presented that the majority of respondents asked for a username and password (80.5%), HTTPS (71%), and inactivity timeout (63%) for their login requirement. Two-factor authentication and SSL are not required by most users. Therefore, the proposed system does not need to add 2FA and SSL features.

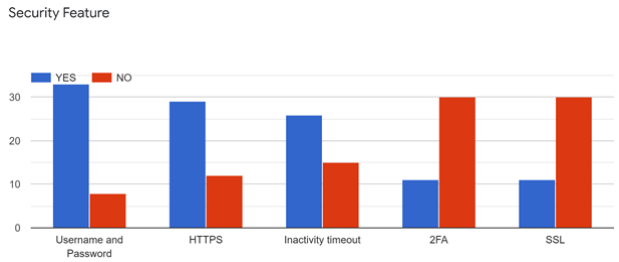

Figure 7. respondents asked for username and password .

Figure 8 displayed the performance issues of the information system. Most of the respondents have specific needs of less than 2 seconds for the response time (68%), processing time (70%), and query and reporting time (83%).

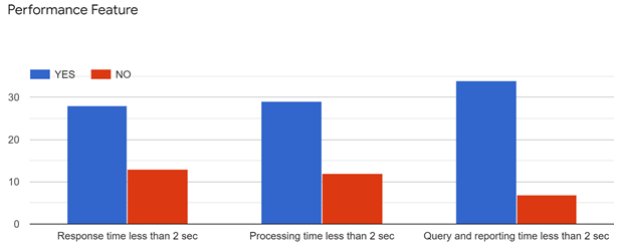

Figure 8. Performance issues of the information system.

Around 72% of users do not ask for the system manual and training manual. After analyzing the above data, the no-functional features and their related requirement were analyzed and described as follows.

- Security: Username and Password, Inactivity timeouts- 5 Minutes, and HTTPS.
- performance: Response times- less than 2 sec, Processing times - less than 5 sec, and Query and Reporting times- less than 10 sec.
- Capacity: Throughput- 10K transaction simultaneously, and Year on growth capacity- 10% every year.
- availability: Hours of operation- 24/7, and Downtime in a month- less than 2%
- recoverability: Recovery time in the event of failure- 5 hours and Automatic data Backup- once daily
- Usability: Interface looks good and Ease to use
- Documentation: User manual

The part-2 of the questionnaire focused on the functional requirements of the proposed system. A total of 41 respondents submitted their opinions. Figure 9 presented the requirements of centralized order management. Around 80% of respondents suggested that the customer get an automatic email notification for order status and business developers can get an automatic email notification on customer requests for assistance. Over 73% of respondents also suggested that users should be able to place an order for all products from a single point and on the other hand business developer will be assigned to assist with user requests.

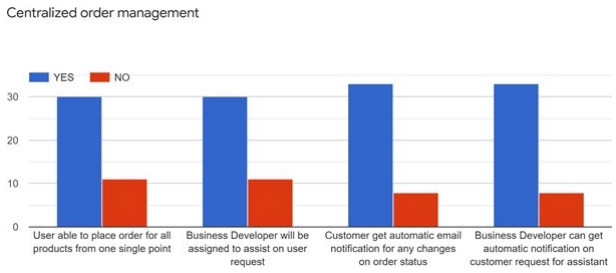

Figure 9. requirements of centralized order management.

Customer management is another important part of the proposed systems shown in Figure 10. 83% of respondents suggested that customers can choose the product and placed it on the basket. Over 70% of the respondents also asked for the requirement of the customer's ability to choose the product design. On the other hand, 73% of respondents suggested that customers should be restricted from changing the order once it is placed on shipping status.

5. Discussion

This section discusses the functional requirement of the analysis as follows.

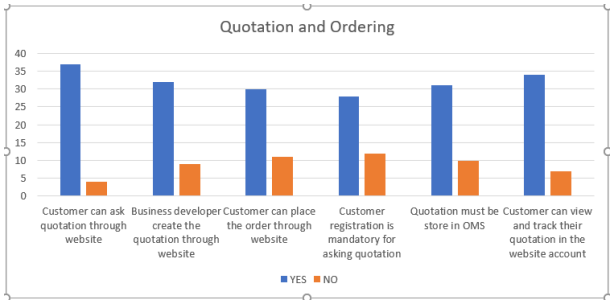

Figure 10. Customer management.

- Components/Features of centralized order management:
  - The system shall allow the user to place the order
  - The system will allow the customer to choose the Business Developer to work with
  - The system shall update the customer on the status of their order through email-notification
  - The system shall not allow changes on the order once its status change to production
- Components/Features of Customer Management:
  - The system shall allow the customer to choose a product size
  - The system shall allow the customer to choose product materials
  - The system shall allow the customer to choose product design
  - The system shall provide the customer with the list of available Business Developer for the consultation session
- Components/Features of Quotation and Order placing:
  - Customer can request a quotation through the organization's website
  - Business Developer creates quotation through website
  - Customer can place the order through the website
  - A quotation must be stored in OMS automatically and quotation automatically sent to the customer through email
  - Customer profile form with a mandatory field of name, phone number, email, and address for registration
  - Customer can view and track their quotation in the website account
- Components/Features of Payment gateways:
  - The system shall provide multiple payments gateway such as (Credit Card, Online Banking)
- Components/Features of Reconciling the order:

  - The OMS automatically interfaces with the accounting information system (AIS)
  - The sale is recorded in a sale ledger in AIS
  - Automatically sent a receipt to the user
- Components/Features of Inventory management:
  - The system should interface with Inventory Management System
  - The system should update the inventory of materials once the customer placed the order
- Components/Features of Fulfillment points integration:
  - The system shall interface with OEM System
  - The system shall be Interface with Distributor Management System
  - The system shall interface with the MIS system
- Components/Features of Shipping services integration:
  - The system shall interface with the shipping services to provide tracking information
- Components/Features of Collaboration (thinking to use Google API for this):
  - The system shall interface with the google meet collaboration tool

6. Conclusions

The key findings of this study proved that the proposed system was found to be primarily fulfilling the organization's requirement and resolving the issues which unsolved in a manual process. Still, this new system may be a challenge for business developers and customers. Consequently, some training may be needed for users to understand the new systems. Additionally, it is recommended that ensure periodic maintenance and data backups in case of system failure. In conclusion, the outcome of this study would play a momentous role for other organizations that do not have an automated sale order management system as a reference.

References

[1] M. A. Al-Shareeda and S. Manickam, "A systematic literature review on security of vehicular ad-hoc network (vanet) based on veins framework," *IEEE Access*, 2023.

[2] P. Balve, H.-H. Wiendahl, and E. Westkämper, "Order management in transformable business structures—basics and concepts," *Robotics and Computer-Integrated Manufacturing*, vol. 17, no. 6, pp. 461–468, 2001.

[3] Z. G. Al-Mekhlafi, M. A. Al-Shareeda, S. Manickam, B. A. Mohammed, A. Alreshidi, M. Alazmi, J. S. Alshudukhi, M. Alsaffar, and T. H. Rassem, "Efficient authentication scheme for 5g-enabled vehicular networks using fog computing," *Sensors*, vol. 23, no. 7, p. 3543, 2023.

[4] V. Venkatasubramanian, "Omnichannel supply chainoms to wms," *International Journal of Innovative Science and Research Technology*, vol. 6, no. 2, pp. 221–231, 2021.

[5] S. U. A. Laghari, S. Manickam, A. K. Al-Ani, M. A. Al-Shareeda, and S. Karuppayah, "Es-secs/gem: An efficient security mechanism for secs/gem communications," *IEEE Access*, vol. 11, pp. 31 813–31 828, 2023.

[6] J. Zheng and H. Khalid, "The adoption of enterprise resource planning and business intelligence systems in small and medium enterprises: A conceptual framework," *Mathematical Problems in Engineering*, vol. 2022, 2022.

[7] S. Sarferaz, *Compendium on Enterprise Resource Planning: Market, Functional and Conceptual View based on SAP S/4HANA*. Springer Nature, 2022.

[8] J. Krüger, "Documentation: Osami management system (oms)," 2011.

[9] W. Astuty, I. Pratama, I. Basir, and J. Harahap, "Does enterprise resource planning lead to the quality of the management accounting information system," *Polish Journal of Management Studies*, vol. 25, no. 2, pp. 93–107, 2022.

[10] B. A. Mohammed, M. A. Al-Shareeda, S. Manickam, Z. G. Al-Mekhlafi, A. M. Alayba, and A. A. Sallam, "Anaa-fog: A novel anonymous authentication scheme for 5g-enabled vehicular fog computing," *Mathematics*, vol. 11, no. 6, p. 1446, 2023.

[11] S. Gupta and M. Sadoghi, "Blockchain transaction processing," *arXiv preprint arXiv:2107.11592*, 2021.

[12] X. Wang, Y. Wang, F. Tao, and A. Liu, "New paradigm of data-driven smart customisation through digital twin," *Journal of manufacturing systems*, vol. 58, pp. 270–280, 2021.

[13] C. Avram, *New paradigms for transaction processing*. Citeseer, 1994.

[14] A. Iswandi *et al.*, "Implementasi chatbot pada order management system usaha mikro kecil menengah (studi kasus hdkreasi)," 2018.

[15] M. A. Al-Shareeda, S. Manickam, M. A. Saare, and N. B. Omar, "Sadetection: Security mechanisms to detect slaac attack in ipv6 link-local network," *Informatica*, vol. 46, no. 9, 2023.

[16] B. A. Mohammed, M. A. Al-Shareeda, S. Manickam, Z. G. Al-Mekhlafi, A. Alreshidi, M. Alazmi, J. S. Alshudukhi, and M. Alsaffar, "Fc-pa: Fog computing-based pseudonym authentication scheme in 5g-enabled vehicular networks," *IEEE Access*, vol. 11, pp. 18 571–18 581, 2023.

[17] Z. G. Al-Mekhlafi, M. A. Al-Shareeda, S. Manickam, B. A. Mohammed, A. Alreshidi, M. Alazmi, J. S. Alshudukhi, M. Alsaffar, and A. Alsewari, "Chebyshev polynomial-based fog computing scheme supporting pseudonym revocation for 5g-enabled vehicular networks," *Electronics*, vol. 12, no. 4, p. 872, 2023.

[18] M. Dachyar and L. Zufri, "Improving order management system in pump industry," *ARPN Journal of Engineering and Applied Sciences*, vol. 11, no. 7, pp. 4917–23, 2016.

[19] A. H. Al Nuaimi and L. G. Williams, "Radioactive waste management in the uae: Proposal for an inventory management system," *Progress in Nuclear Energy*, vol. 146, p. 104140, 2022.

[20] M. A. Al-Shareeda, S. Manickam, and M. A. Saare, "Ddos attacks detection using machine learning and deep learning techniques: analysis and comparison," *Bulletin of Electrical Engineering and Informatics*, vol. 12, no. 2, pp. 930–939, 2023.

[21] M. A. Al-Shareeda, S. Manickam, M. A. Saare, and

N. C. Arjuman, "Proposed security mechanism for preventing fake router advertisement attack in ipv6 link-local network," *Indones. J. Electr. Eng. Comput. Sci*, vol. 29, pp. 518–526, 2023.

[22] R. Nepal, R. Sofe, T. Jamasb, and V. Ramiah, "Independent power producers and deregulation in an island based small electricity system: The case of papua new guinea," *Energy Policy*, vol. 172, p. 113291, 2023.

[23] C. Saha, F. Aqlan, S. S. Lam, and W. Boldrin, "A decision support system for real-time order management in a heterogeneous production environment," *Expert Systems with Applications*, vol. 60, pp. 16–26, 2016.

[24] Z. G. Al-Mekhlafi, M. A. Al-Shareeda, S. Manickam, B. A. Mohammed, and A. Qtaish, "Lattice-based lightweight quantum resistant scheme in 5g-enabled vehicular networks," *Mathematics*, vol. 11, no. 2, p. 399, 2023.