

New Directions for Warehousing Data Management Research: Extensions to an Existing Review

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Abstract—Existing research has conducted reviews of warehousing research and has suggested potential important areas for future work. In this paper we focus on warehousing data management-related issues and augment the findings from a recent review of warehousing research to suggest new areas of future work. To determine these potential areas we visited a large, national warehousing organisation and observed their warehouses, operations, and information systems. We compared our findings against the recommendations from an academic review, and identified five new areas of important future research.

I. INTRODUCTION

In this paper we extend an existing, and comprehensive, review of warehousing research by Davarzani and Norrman [1], in order to:

- 1) validate the existing review to determine whether the specific issues we found in a large warehousing company match those of the review, and
- 2) identify further potential warehousing data management-related research, which has not currently been identified in the existing review.

For our methodology, we adopted an approach which Davarzani and Norrman did not use to determine areas of future research in their paper: direct observation of the issues in a warehouse. For this we visited a large, national warehousing company and observed numerous warehouse sites, the associated operations and information technology systems used. Davarzani and Norrman applied an academic literature review and interviews with warehousing practitioners in order to establish an agenda for future warehousing research. For our first aim, our work therefore builds on their research by validating their results i.e. determines how well the issues in an actual warehouse match their recommendations for future problems to solve. For our second aim, we focussed on the completeness of their results and identified new suggestions for research, which extends their review. Our results indicate five new areas of warehousing data management-related research which academic researchers and practitioners could investigate.

The paper proceeds with a brief description of academic warehousing literature reviews, followed by a description of the methodology we used to identify overlapping and new research areas in warehousing. We then present the results and discuss the five new areas of research before providing concluding remarks.

II. EXISTING WAREHOUSING LITERATURE REVIEWS

Gu et al. [2] presented the most common warehouse operational problems based on an academic review where most of the papers were published before 2000. Warehouse operational problems are clustered as; receiving and shipping, storage, and order picking. Later, Gu et al. [3] presented another study which is a continuation of their first warehouse research. This review paper highlights academic research based on four subsections: warehouse design, performance evaluation, case studies, and computational support tools. Warehouse design problems are clustered as overall structure, sizing and dimensioning, department layout, equipment selection, and operation strategy. The performance evaluation subsection describes the approaches used in academia to provide feedback about the proposed warehouse design.

Gong and Koster [4] conducted a review on the uncertainty sources of warehouses and stochastic models to address these uncertainties. Additionally, they pointed out the limitations related to model parameters and processes being used in stochastic modelling.

Koster et al. [5] conducted a literature survey only focusing on the decision problem in design and control of manual order-picking.

Davarzani and Norrmans [1] research highlights the most important warehouse research areas from both academic and a practitioners point of view. Their review paper is currently the most recently published paper including many sources published after 2000 as well as covering all research areas related to warehousing. Hence, we selected this paper for the basis of our analysis. From hereon we refer to this paper as “the review”.

III. METHODOLOGY

In order to carry out our assessment, we chose deliberately to conduct it without having any knowledge of the results of the review. That is, we did not inspect the results of the Davarzani and Norrman review paper prior to capturing and documenting the key issues in the warehousing organisation. In this way, we were not biased to see what we expected to see during our observations. Once our warehouse visits were completed, and the requirements had been documented, we examined the review paper and analysed the academic

literature review section and the practitioner interview section to identify requirement overlaps.

A. Direct Observations of Warehousing Operations

The warehousing organisation we worked with is taking a diligent approach to improving their operations, and our aim for them was to capture and provide them with new requirements for their warehousing IT system, so that it could be improved in the future to cope with the problems we identified. We use the term “requirements” in this paper because our observed warehousing problems become requirements for future research.

However, we did limit the scope of our work to warehousing problems that have some connection to the warehousing information technology systems; in order to observe every single problem in the warehousing company was clearly not feasible, and hence the reason for this scoping. Many problems, of course, relate back to the IT system and therefore this scope was still broad enough to capture a multitude of problems.

During our observations we visited eight warehouses as well as the headquarters of a large warehousing organisation to oversee the operations and speak to the senior management over a period of nine days. In these visits we observed various types of operations for different types of warehouses including, for instance, Vendor Managed Inventory (VMI), the standard warehousing operations (storing, picking, shipping etc.), consolidation planning, and the various information technology systems.

B. Analysis Procedure

We followed a three step procedure to identify the various overlaps between the requirements from our direct observations and the requirements in the review.

First of all, three researchers (the authors PW, GY and VG) reviewed the review paper independently (i.e. without showing each other the results) to identify the following:

- Requirements that corroborate with the direct observation requirements
- Requirements in the directly observed requirements which are not in the requirements from the review.

For the individual review process, a review template was created and used by each researcher. An example of part of the review template is shown in Table I¹; for every requirement in the direct observation (first column) we recorded the sections of the paper which also describe this requirement (second and third columns). Also any comments to help the three researchers to reach a consensus were recorded in the final column.

An important point related to Step 1 was that the researchers only looked to find whether the directly observed requirements were in the paper. We did not extract all requirements from the paper and then check them against the directly observed requirements.

TABLE I. AN EXAMPLE OF PART OF THE REVIEW TEMPLATE USED TO RECORD THE OVERLAPPING REQUIREMENTS

Observation requirement No./name	Related phrase(s) in the review paper	Section	Comments
8. KPIs for individual staff and business	The necessity of having well-defined KPIs is the most commonly expressed concern. It is important to establish correct understanding of the performance and measure it in the right way.	4.5	—
	The importance of defining appropriate KPIs is well received by scholars.	5.1.5	Seems to be a slightly different focus: related to the definition of KPIs rather than reporting

For the second step, a meeting was held where the three researchers discussed any conflicts between their results, with the aim of reaching a consensus. In this step there were two possible cases for each observed requirement:

- 1) The findings of each researcher agreed.
- 2) Findings from each researcher did not agree.

If all three researchers agreed, then the researchers still discussed their interpretations to double-check them. However, if the situation was the second case, then each researcher made their own arguments based on their findings and try to convince the others to reach a consensus.

As a third and final step, the arguments and results were documented and each person briefly reviewed them to check that all conflicts resolutions had been correctly applied.

IV. REQUIREMENTS FOR FUTURE WAREHOUSING RESEARCH

This section reports the results of our analysis of which requirements from the direct observation overlap with the requirements from the review. Table II lists the new requirements that were obtained from the observation and were not in the review. In some cases, a requirement may have been partially described or hinted at in the review, but not explicitly reported in full; in these cases we describe what the overlapping and new specific points are. Table III lists the requirements from the direct observation that were also reported in the review (i.e. those that corroborate) —again, the level of overlap is described.

Requirement 2 is partially referred to in the review, but in the direct observation some further issues were noted. The review raises the issue of the accuracy of the data about inventory and storage locations. This covers only part of our requirement 2, which states that warehouse IT systems need to be able to accurately report product data (e.g. type, size etc.), locations and the state of the products. In this case the state refers to whether the product is in storage, in shipping and what stage in shipping, in packing, is a returned product etc. We also include in this requirement that the “data process” in general needs to be aligned with the physical process (i.e. operations). Hence, these latter two points are an extension to what is said in the review, and, in particular, the company sees

¹All data templates are available on request

TABLE II. NEW REQUIREMENTS FOUND IN THE DIRECT OBSERVATION AND NOT IN THE REVIEW

Index	Requirement description
1	The system must be flexible enough to allow data to be entered into the system at the time it is actually known, rather than when it is expected to be known within the physical process.
2	The data processes in the warehouse need to be aligned with the physical process (operations) in the warehouse. So that warehouse information systems are able to provide detailed and accurate reports about the product and its actual state (e.g. on a shelf, on a picking device, in the buffer zone waiting to be picked), as well as their status before they arrive at and after they leave the warehouse.
3	Warehousing-related data should be available in multiple locations (wherever the person needing it is) in order for the right decision to be made at the required point in time.
4	Warehousing information systems should be able to produce tailored reports according to the specific requirements of each stakeholder (inside or outside the organisation). As these stakeholders can change frequently, the reporting mechanism needs to be flexible enough to cope with this.
5	As a warehousing organisation acquires other firms (such as other warehouses or transportation providers etc.) it is necessary to determine how and whether to incorporate these into the business; for example, should the systems be merged into a single unified system?

the need to align the data process with the physical process as a critical area not just within inventory and storage. One example of when these go awry is when a warehouse operator moves products from one location to another and does not update this location change in the information system. The misalignment between these pervades the entire warehousing and logistics operations space, and is a significant problem to address.

Requirements 1, 3, 4 and 5 are new requirements that were recorded in the direct observation and were not included in the review.

Requirement 1 suggests that further research is needed to identify solutions to the problem of the IT systems not being flexible enough to allow data to be entered at the time it is actually known, rather than when it is expected to be known. In some cases, the IT system forces users to enter values which may not be revealed until later in the process. In this case we observed users entering a default value or some “placeholder” value, which satisfies the IT system’s validation constraints, and they aim to enter the correct value later when it becomes known. However, the users do not always come back to update the system which then contains incorrect information. Novel solutions to this problem are therefore required.

Requirement 3 notes the problem of staff not always having access to the data they need, such as having an up-to-date shipping order when the list of products being shipped can change frequently. This has two parts: the hardware needed to provide access to the data (such as handheld devices etc.) and the algorithms to dynamically determine what pieces of data each users needs.

Requirement 4 refers to the problem of needing to report and process data in different ways for each supplier and client of the warehousing organisation. Depending on contractual details, the information requirements that need to be reported to the supplier and client may differ. For instance, if the warehouse provides various services such as re-packaging, then the supplier will likely require a record of what items have been re-packaged. The key issues are therefore how to have the infrastructure (both hardware and software) in place so that

TABLE III. CORROBORATING REQUIREMENTS IN THE REVIEW AND IN THE DIRECT OBSERVATION

Index	Requirement description
6	A requirement of the warehousing-related IT system is that it should have the ability to cope with all the situations that do not fit the “normal” process (because of exceptions, disruptions etc.) as well as with higher-level variances that arise within the warehousing operations (such as different sales channels, levels of automation in the warehouse etc.).
7	The warehouse information system must cope with and integrate successfully with supply chain stages that are not executed/owned by the organisation.
8	For the better measurement of the performance of the warehousing organisation, the information system should be able to provide KPIs at the individual (staff) level as well as provide aggregated KPIs at the business level.
9	Customers of the warehouse company should be able to automatically select and configure their services package from the warehouse depending on their individual needs. For instance, if a customer requires a re-packing service, then the customer should be able to select this and the information system should be able to provide the relevant data reports automatically.
10	With the rise of e-commerce and omni-channel sales, Business to Consumer (B2C) commerce will become more and more important for logistics organisations as they will have to prepare and deliver orders to end-customers rather than to businesses. B2B will also become more like B2C as businesses request more individual orders of specific products.
11	Data should be efficiently shared between any warehouse-related IT systems e.g. within departments or between different organisations.

for any new set of information requirements, the warehousing organisation can easily provide the relevant reports.

Requirement 5 concerns the need to incorporate the warehousing and related IT systems from other warehousing-related organisations (warehouses, transportation providers etc.) as they merge. The problem is how and whether to transition from two systems into a single unified system. This is clearly only an important requirement for organisations wishing to expand through mergers and acquisitions.

The remaining requirements (6 to 11), listed in Table III, have already been recommended as future work in the review.

V. CONCLUSION

Six out of the eleven requirements we identified in our observations of warehousing operations also appeared in the future research suggestions of the review by Davarzani and Norrman thus validating those outputs in the review. However, we also identified five new requirements for future warehousing research related to warehousing information systems. The most important requirement that we observed that was not fully explicated in the review paper is for the need of the physical process to be aligned with the data process in all warehousing operations. Being able to enter data and view data reports when needed and not as dictated by a “static”, inflexible information system are two other important problems needing attention. The final new area for future research is related to how to merge warehousing information systems from different organisations, which is critical for warehousing companies who wish to expand via mergers and acquisitions.

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