Increasing the Operational Efficiency of a Commercial Laundry: Layout Optimization and Process Automation

Jeremy Spiteri and Michael A. Saliba*

Department of Industrial and Manufacturing Engineering
University of Malta
Msida, MSD 2080, Malta

Abstract

Commercial laundries typically are required to address significant variability and complexity in process inputs, such as size, material, and colour of the items of fabric to be washed; the identification of pre-existing defects in the items; complex and variable routing of the items during the laundry process; variable drying times; sorting issues due to different wash cycle requirements; item storage; and the organisation of item despatch to different geographical areas. Due to these problems, operations in commercial laundries are rarely optimized, and generally do not apply automation. In this work, we study the operations in a commercial laundry, with the aim of optimizing the process and the factory layout to achieve a five day (i.e. one week) turnaround time of items being processed by the company. We focus on one class of items (quilts) during the peak laundry period for this item (Summer). We have developed a detailed simulation of the laundry operations, and use this program to optimize specific parameters of the factory, such as the floor layout, the number of washing machines, and the sorting and tracking methodologies, based on typical work volumes, with the aim of achieving the required turnaround times for all items to be processed. In the second part of our work we present the conceptual design of a system that improves and/or automates the transport, tracking, washing, drying and sorting of the quilts in the presence of high process variability, and taking into account the highly deformable nature of the items and the space limitations.

1. Introduction

Professional laundries are generalised into two different categories, commercial (or domestic) and industrial. What distinguishes the two is the type of clientele of the laundry cleaner; commercial laundries cater for the general public, whilst industrial laundries cater for hotels, restaurants and factories. The laundries that are turning towards automation tend to be of the industrial type, since it is much easier to automate a process that involves large numbers of identical items. The laundry plant that is being considered in this work, however, is a commercial laundry, catering for the general public. Thus, laundry items vary in size, colour and material. The laundry items are categorised in three types; Coloured, Whites, and Delicates; but even though each laundry item received from the customers falls in one of these categories, all items are still different in more than these three ways, and this is what makes automation more difficult to implement.

In most cases, when considering the possibility of automation, laundry owners are thrown off by the idea that automation comes at a high price, but this is rarely the case [1]. Investing wisely in automation proves to be cost effective, and often results in an expanded work load, followed by an increase in profit. But before thinking about installing automation equipment one must study how to re-arrange the shop floor. When re-arranging a shop floor, one of the most important considerations is that of work flow [2]. Usually space is the first priority, even though it will always be a potential problem in any section; indeed monorails are becoming more important in laundries, be they commercial or industrial. Therefore, in this work, the conceptual developments of the new layout of the laundry and of the proposed automation were carried out concurrently.

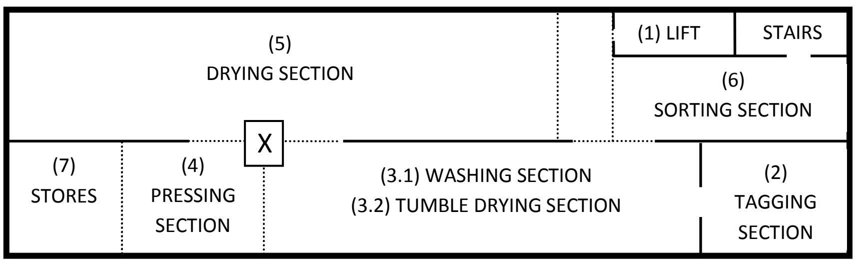
When automating a laundry system, item tracking is very important. In this regard, RFIDs are preferable to barcodes because they make automation much simpler, and remove the constraint of being able to track items only within line of sight [3], [4]. They also aid the automated process by sending information directly to the programmable logic controllers, and with the information received, laundry can be sorted automatically [5].

* Corresponding author: Tel.: (356) 2340-2924; Fax: (356) 2134-3577; E-mail: michael.saliba@um.edu.mt

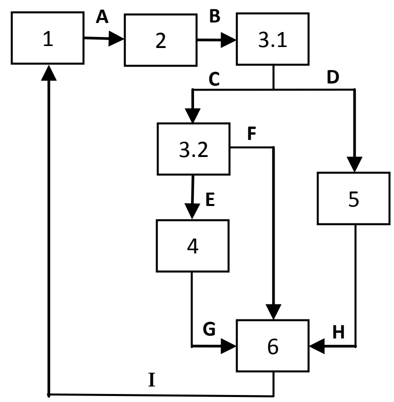
What follows, is therefore the study conducted in order to improve the laundry under consideration to make it more efficient. The first steps were to carry out an investigation of current operations, followed by the generation of ideas that could make the entire section more efficient. Details about each proposition are given in the respective sections.

2. PROBLEM BACKGROUND

Figure 1 below depicts the diagram for all process paths in the laundry section of the company, together with the layout of the shop floor. Note that in the figure, dotted lines are present to mark the section boundaries, whilst solid lines indicate walls. It is also important to note that the dotted line between the drying section and the lift is drawn to indicate that obstacles such as trolleys full of quilts fill this buffer area, thus closing this passage. Therefore the mark X, on Figure 1, indicates the only entry and exit to the drying section.



(a)



(b)

FIGURE 1: (a) Shop floor diagram and (b) Process diagram

The flow of all laundry is labelled with letters on Figure 1, which are explained below.

A - All laundry is sent up from the ground floor, the driver's section, and comes out from the lift (1). The laundry arriving from the lift is transported manually on trolleys to the Tagging section (2).
B -After the laundry is tagged, using barcodes, it is moved to the washing section (3.1), where there are currently two large washing machines for quilts and soft toys, and an additional two for personal laundry.
C – All washed laundry, except for quilts and soft toys, is moved to the tumble drying section (3.2), where there are currently four operational tumble dryers.
D - Quilts on the other hand, are moved to the drying section (5) through point X .
E, F - After tumble drying, laundry either moves towards the pressing section (4) or towards the sorting section (6) immediately, depending on the type of laundry.
G – Items transferred to pressing (4), once completed, are then moved to sorting (6).
H - Quilts are transferred to sorting (6), again through point X, after they have dried, which they usually do overnight.
I - Laundry is then sorted using the barcodes, packed, placed in trolleys, and waits to be put back in the lift (1) to be sent downstairs for delivery.

As can be inferred from Figure 2, the flow of quilts around the laundry section is very far from optimal.

Table 1 shows how the quilts would normally go through the factory, during the off peak season. As can be seen from the cycle, the work in process days are four, from Day 2 to Day 5. Pickup and delivery days are not included as work in process days for the quilt.

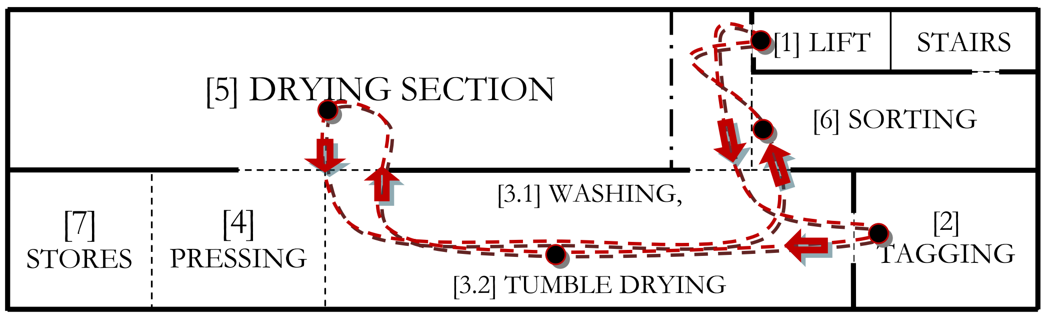


FIGURE 2: Current shop floor layout and movement path

Table 1: The Laundry Cycle for quilts

Day 1	Laundry picked up from Customer
Day 2	Laundry starts the tagging Process; checked at the same time
Day 3	Washing of Laundry; and hung to dry, in drying section
Day 4	Removed from drying; Sorting/Checking/Packing stage starts
Day 5	Sorting/Checking/Packing stage; sent to warehouse
Day 6	Laundry Delivered to Customer

Note: Day 1 and Day 6 are the same day of the week, that is, pick-up and delivery days are the same day of the week. Saturday and Sunday are excluded from the working week.

Unfortunately, when the peak season (summer) hits, the cycle indicated above does not apply any more, since quilt numbers increase considerably. Thus instead of taking four days work in process, quilts take as much as seven days. This causes quilts to miss return delivery dates, as drivers visit specific locations only once a week on specific days, for the majority of the locations.

This problem, in increased processing days per quilt, implies that in summer the company is unable to offer a one week delivery service, and is instead forced to prolong this to two weeks. This causes large batches of laundry to be stored in the drivers' section, with some laundries staying there even for nearly a whole week. This causes clutter, since the space is very limited; and space is a significant cost.

3. Simulating the Shop floor

Before proposing improvements, it was important to obtain a thorough understanding of the current process, so that this could be compared to any proposal that is put forward.

Thus, we developed a simulation compiled with the aid of Visual Studio, using the C# language, where the times for the main processes that affect the cycle for quilts, mainly tagging, washing and sorting were compiled using real data (from the company records) for customer demand during the peak season. The simulation took into account the resources and layout of the current system (e.g. number of washing machines, quilt transfer time between stations) in order to give a clear indication when each quilt would be finished. The working hours of the company employees were also inputted.

The program was compiled in a way to keep it as close as possible to the actual processes being carried out in the factory. A time study was conducted to find the average times of each process, and then the program was constructed in a way that the times could be changed in order to compare any proposals for changes to the system. As the program loads, a window appears showing the start date and end date to be chosen by the user (with the help of calendars) and a run button. As the user clicks on run, the dates are brought up in variables from the calendars. The quantities are picked up from the database (e.g. quilt amounts obtained from the company records) and for each day in between the start and the end date the program calculates how many quilts would be processed for each day under the prevailing constraints. Part of the program output is shown in Figure 3.

The objective of the program was to show exactly what occurs in the laundry plant in the peak season. The simulation, based on the existing layout and configuration, resulted in a work in process average of five days per quilt, with a maximum of seven days work in process. This result was in general agreement with the performance records of the company.

As can be seen from Figure 3, the results were as expected, where in the summer periods the bottleneck in the system are the washing machines, where as many as four days of work in process were present. Where such a quilt spends also one day in tagging and two days in the sorting section, this results in a maximum of seven days processing time. The second bottleneck was in fact identified to be the sorting section.

Incoming Date	Qilt Code	Processing Days	Days in Tagging	Days in Washing	Days in Sorting
20/03/2009 00:0...	FriQ	7	1	4	2
20/03/2009 00:0...	FriQ	7	1	4	2
20/03/2009 00:0...	FriQ	7	1	4	2
20/03/2009 00:0...	FriQ	7	1	4	2
20/03/2009 00:0...	FriQ	7	1	4	2
20/03/2009 00:0...	FriQ	7	1	4	2

FIGURE 3: Program Screenshot, showing current maximum processing days, 7.

The fact that the *average* work in process time is five days per quilt, confirms the clutter that is present in the plant in the peak season, where many ready quilts are stored to await their delivery date in a week's time, having missed their primary delivery date.

Apart from the problem that the washing machines cannot cope with the amount of quilts that are to be processed per day in the peak season, there is also the problem of drying space. Thus the owner cannot keep workers on overtime to wash any remaining quilts for the day, as there would not be enough space to hang the quilts to dry. Drying space is therefore a problem that also needs to be tackled.

4. Generation of Concepts

A number of different solution concepts were generated to address the various problems described above.

The current shop floor layout in the laundry section came about as a result of a change in the laundry plant structure that took place four years ago. As a result of an increase in structural area, organisation of the shop floor took place at a time when the peak season was fast approaching. Therefore the shop floor was not planned thoroughly, but merely selected by space available.

The first conceptual sketch that was drawn, seen in Figure 4, was a preferred shop floor plan layout, where the quilts would go through consecutive sections located next to each other, ending their cycle back at the lift (1). Note that the drying section (5) needs to be very close to both the washing (3) and sorting (6) sections. The lift needs to be close to both the tagging (2) and sorting (6) sections. The pressing section (4) and stores (7) were not given priority, since quilts were the main focus of this study.

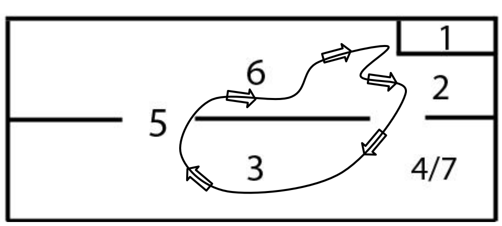


FIGURE 4: Sketched ideal shop floor with ideal process path

The separate processes were then viewed one by one, and concepts were drawn up to make each process simpler and less time consuming. The ergonomics with the worker were studied first, in order to design the concept around the worker, and not the other way round. Each concept was left as simple as possible in order to spark a final idea for what would then be the final proposition for the laundry section.

The first section that was considered was the tagging section. Since all laundry would first go through this section, what was kept in mind was that efficiency and organisation are extremely important here, since all the following sections depend on this stage. What was studied in this section was the tagging process itself, that is, what the worker does to the laundry, how he does it, and why. After gathering the required technical information, we asked the worker for input on the process, and for suggestions for improvement.

Unfortunately, given the nature of the process, that is, manually checking laundry for any defects and inputting information into the system, automation of the process was considered unfeasible. Using machine vision would be extremely difficult, given the vast variation of the laundry and of potential defects. What was sketched however was a solution that could link the tagging section to the washing section. Initial sketches involved chutes that would slide the sorted laundry (whites, colours and delicates) into respective trolleys, but although this would improve the time to start the washing process, clutter would still be present on the shop floor. Following this idea, the concept of using collection sacks was drawn up. Collection sacks would be used to separate the laundry, but with the additional advantage, over chutes, that the laundry could now be lifted above the shop floor, creating additional space. As this concept started to take shape, new concepts for the washing section also started to evolve.

Given the concept of collection sacks instead of trolleys, new designs for loading and unloading of washing machines had to be drafted. Since the collection sacks would be lifted above the shop floor, the washing machines would need to be vertically loaded, i.e. from above. The unloading stage was treated separately. Concepts for unloading the machines included the use of robotic arms removing the laundry one by one. Quilts are very deformable in nature however, thus if no reference points are present on the quilt, automation is a difficult task to achieve.

The drying section, on the other hand, was different. Once the quilt was hung to dry, automating the process would be easier as the quilts could then be separated and controlled. Thus, the idea of a conveyor started to take shape. As can be seen from Figure 5, a conveyor acting as a means of both drying and transportation was the initial idea, and since there was the need to move from one section to another, hanging and removing could be achieved from each respective section; i.e. hanging from washing section, and removing from the sorting section. Another important benefit that could be achieved by using a conveyor was the ability to move quilts in the vertical direction, using the entire shop volume to a major extent; two levels of drying space could be achieved.

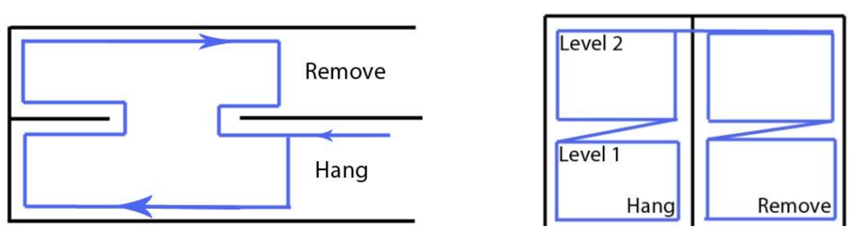


FIGURE 5: Plan and front view (respectively) sketch of conveyor path from hanging to removing

The sorting process, as does the drying process, involves transportation of quilts from one place to another. A system had to be designed, where quilts could be stored, and once sorted, returned back to the packing table; or be self packed. Many concepts were drawn up, but unfortunately the majority of the concepts were seen to potentially cause more problems than they would solve, as it became clear that this section was more difficult to automate than expected. This is because the quilts that arrive in this section are currently hand folded and put in trolleys in various orientations. Some of the solution concepts sketched included robotic arms with end effectors designed to lift folded quilts and place them in pigeon holes, also concepts that elevate and push quilts to their respective position in the sorting tray.

5. Final Proposals

After an evaluation and selection stage, the final proposals were given for each process, and the shop floor designed in more detail. The proposed concept for the shop floor layout can be seen in Figure 6.

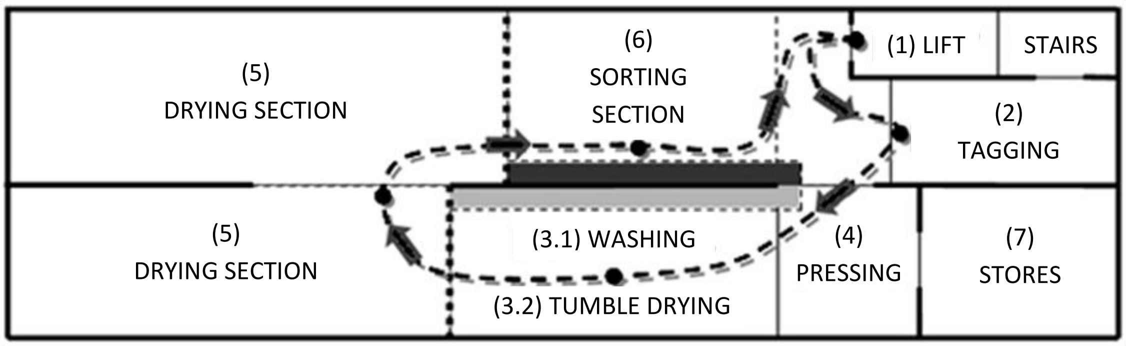


FIGURE 6: Proposed shop floor, and quilt movement path

What should also be noted in Figure 6, are the light grey and darker shaded grey areas which indicate where the worker would hang and remove the quilts respectively. By restricting hanging and removal of the quilts to two positions, worker movement is reduced. Restricting unnecessary movement reduces operation time as well as clutter on the shop floor.

For the tagging process, the main sketches were all aimed to sort the quilts manually into three; whites, colours, and delicates. The sorted quilts would then be sent to the washing section in order to start their respective washing cycle. The final proposals for this section where the following: RFID chips to replace barcodes; initial sorting of quilts at this stage into whites, colours and delicates; and sorted quilts placed in collection sacks instead of trolleys.

For the washing process, the selection as to where the unloading position should be in the washing machine was chosen given the fact that no automated process, from washing machine to the drying section, could be evaluated as feasible. Therefore this evaluation gave rise to the proposed use of an additional horizontal unloading and top loading washing machine. The final proposals for this section where the following: increasing the number of washing machines by one; the use of top loading washing machines with front (horizontal) extracting laundry; with the hanging of wet quilts carried out in front of the machines themselves, and limited to one section – shaded in light grey in Figure 6. By implementing these proposed ideas for the washing process, the quilts would be automatically washed, followed by manual removal, and hanging in the same section.

The drying and sorting processes, combined together, resulted in a great opportunity to solve many problems that the company is facing right now; by proposing the implementation of an innovative conveyor system. Therefore what follow are the final proposals for this section: introduce a new conveyor system to have more control on each quilt; such a system would then allow sealing of the drying section and the implementation of heat ducts to control the environment for minimum drying time; then, construct two levels of drying space by implementing a two-level conveyor system, thus increasing the drying area by almost twice. Sorting of the quilts would be automated; hanging and removal of quilts would be limited to one position – shaded in light grey and dark grey in Figure 6, respectively. Moisture sensors on the quilt hangers would monitor the stage of the drying process for each quilt.

By implementing the proposed conveyor, the system would demand controlling software, which would monitor each quilt at every location along the conveyor. Therefore each quilt will be one hundred percent traceable, once tagged, along the entire shop floor in the laundry section.

6. Simulation of the Proposed System

After all the proposals were presented to the owner of the company, and approved as possible ideas, a study was carried out using our simulation program, to find out the effects on the work in process times (in working days per quilt) of the proposals. Therefore a new time study was conducted to obtain the average times for each proposed new process. The new times were input in the program to obtain the new results.

Incoming Date	Qilt Code	Processing Days	Days in Tagging	Days in Washing	Days in Sorting
20/03/2009 00:0...	FriQ	4	1	2	1
20/03/2009 00:0...	FriQ	4	1	2	1
20/03/2009 00:0...	FriQ	4	1	2	1
20/03/2009 00:0...	FriQ	4	1	2	1

FIGURE 7: Program Screenshot showing maximum processing days after proposals, 4.

As can be seen from Figure 7, given all the proposals that were mentioned in section 5, the maximum time for one quilt to be finished during the peak season, came down to just four days from seven, giving the same result that the company is currently achieving during the lean season.

7. AUTOMATING THE DRYING CYCLE: CONCEPTUAL DESIGN CONSIDERATIONS

Even though initial sketches were drawn in the brainstorming session, once the conveyor was selected as the preferred proposal, more detailed designs started to take shape. In order for the conveyor to be effective and innovative, it had to adapt for every quilt a customer could send; dry it, and sort it.

After several sketches for the conveyor, the idea of variable length carriers, suspended on clip pairs on a rail was chosen, since this gave flexibility for sizes, and for individual sorting of the quilts. Separate carriers would give the quilts the independence they needed from one another, as can be seen from the conceptual drawing in Figure 8.

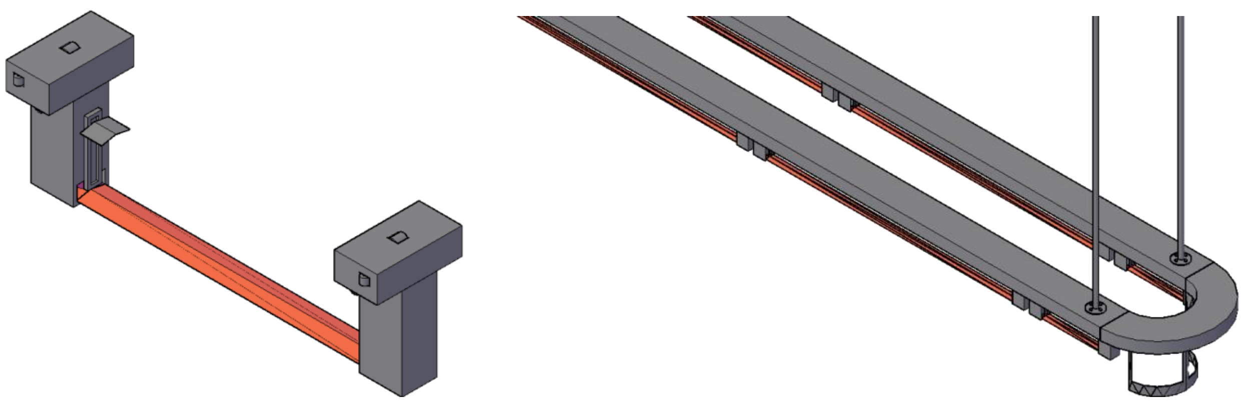


FIGURE 8: Conceptual Drawings of Clip Pairs, and Rail Turn, respectively

What was needed after the sketching was complete was to calculate the minimum size required for the conveyor, in order for the structure not to fail under load. The calculations involved drawing a free body diagram of the loaded structure, with a span of five metres from one support to the other. Given that the maximum weight of a wet queen size quilt is approximately 8 kg, the calculations were taken with a safety factor of 1.5; therefore each quilt was calculated at a weight of 12 kg. Given the structure, each quilt would be exerting forces at two specific points on the conveyor rail, due to the clips.

After the necessary calculations, a 3D model of the conveyor and the clip pairs was generated using computer aided design. Figure 9 depicts how the conveyor would look assembled on the shop floor. Also depicted in Figure 9, are some quilts hanging from the clip pairs.

FIGURE 9: 3D model of installed conveyor, with hanging quilts.

8. Conclusion

The objective of this work was to increase the operational efficiency of this commercial laundry, and it was shown that with the new proposals, the amount of work in process hours per quilt would decrease substantially, primarily during the peak seasons.

Decreasing the work in process hours would be profitable in more ways than one. Apart from the fact that the company would now be able to enhance its reputation of delivering quilts in one week's time even in summer, as opposed to its competitors, another other major advantage to the company was found to be the removal of at least one of the workers, given the automated processes. This would amount to a substantial reduction in labour costs. Also, given the tool of automation, the company would stand out from its competitors as a more modern professional laundry factory, which would give it an edge in increasing its clientele.

Competing in today's market involves using every possible and available asset, but certain assets are available to all. It is that extra asset that is available to the company that marks a clear separation from its rivals.

Future work that may be implemented, in addition to the results obtained herein, should be aimed to decrease even further the work in process hours per quilt, always keeping in mind feasibility and flexibility. A potential proposal would be to start the laundry cycle from before the quilt enters the laundry section, from the client himself. Including client involvement would ease the cycle, and reduce the work in process time in the laundry section. Client relationships are extremely important in modern businesses, therefore client involvement could lead to a potential increase in clientele.

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