An Investigation into Technological Potentials of Library Intralogistics Operations

Niloofar Jafari[1](✉), Fabio Sgarbossa[1], Bjørn Tore Nyland[2], and Arild Sorheim[2]

[1] Department of Mechanical and Industrial Engineering, Faculty of Engineering, NTNU Norwegian University of Science and Technology, Trondheim, Norway
[niloofar.jafari, fabio.sgarbossa]@ntnu.no
[2] Trondheim Public Library, Municipality of Trondheim, Trondheim, Norway
[bjorn-tore.nyland, arild.sorheim]@trondheim.kommune.no

Abstract. The efficiency of operations in service-oriented organizations is amongst the primary objectives. Libraries are no exception in this context, and this goal becomes even more complex due to being a non-profitable entity. While recent technological improvements have favored organizations in various dimensions, there is a technological lag in library operations. Through adoption of input-transformation-output model to elaborate the library operations, and using Trondheim Public Library as the case study, material processing turns out as the dominant element of transformation processes. Given the solid link between material processing and intralogistics operations—and material handling—this study collects a list of technological and digital solutions that have contributed to this realm, by exploiting the principles of systematic literature review. According to four areas of material processing in library, i.e., moving, sorting, storing, and controlling, an exploratory study of the applicability of technologies is conducted at the Trondheim Public Library as the case study. Moreover, through focus group discussions with librarians and authors, the operational function of each identified solution is measured across four key performance indicators (KPIs). This leads to generating a first pragmatic profile for each technology that assists libraries in better decision making for adoption of digital solutions in favor of upbuilding their operations. The findings are, however, not conclusive due to the exploratory aspect of this study and to fast-paced advances in the current digital era, and in this regard, some of the significant considerations along with possible limitations and future research are put into discussions.

Keywords: Library, Technology, Material Handling, Intralogistics

1 Introduction

Libraries in societies are recognized as organizations with vital missions set to contribute into knowledge development, as well as preserving the world's collective knowledge and intellectual heritage for future generations. In the current form of societies, these organizations are in charge of various services that are not limited to lending scientific materials, but also extended to other agendas, e.g., language cours-

es, group meetings, etc., which generally contribute to the enhancement of economic, social, and cultural development in society [1]. Recent improvements in computer and information science, have provided libraries with more efficient platforms and tools to offer electronic services and e-format materials [2]. Thanks to this digital transition, library users, so-called *patrons*, can access several services and materials through the internet-based platforms without visiting library. However, this does not imply that the physical environment of libraries are less required and will no longer exist [3]. "The end of the book" or "The end of libraries" are misguiding phrases; in fact, libraries, by taking the advantages of digital solutions, are equipped with more efficient tools that not only favor in better archiving and preserving the knowledge, but also facilitate more effective performance in approaching its goals, i.e., sharing information, preserving knowledge, etc. [4].

Provision of services is the main function of organizations, and this objective is directly supported by various operations performed to deliver the desired services [5], and libraries are no exception in this context. While operations vary on the basis of required services, the logical structure of operations adheres to the concept of 'input-transformation-output' model, in which transformation processes adopt diverse inputs to create the demanded products and services [6, 7]. For instance, 'making a book available' is an operation performed in libraries, and it encompasses several processes such that a patron can borrow and receive the ordered book [6]. Transformation processes are high in priority and divided into three categories: material processing, information processing, and customer processing. On one hand, an articulation of prominent operations of library signifies that material processes are logistics-related [8]. On the other hand, and compared to other organizations, a considerable technological lag is observed in libraries and particularly in conjunction with transformation processes, which are resource intensive and performed widely manually. This correlation elucidates that there is a remarkable potential to improve the efficiency of library operations through digitalizing the transformation processes by taking the advantages of technological improvements that benefited logistics and/or intralogistics.

Intralogistics—defined as perception and optimization of internal flow of material—has extensively benefited from the technological advancements throughout the last decades [9]. This scope is equivalently recognized as operational and functional agendas pertinent to material handling, which encompass moving, protecting, storing, and controlling the materials in a plant [10]. Effective material handling helps organizations to operate more efficiently and reliably [11], and nowadays thanks to the latest technological and digital improvements, material handling has been substantially transmitted from pure manual towards automated processes. Dynamic storage allocation, automated storage and retrieval systems (ASRS), robotic piece-picking solutions, and automated material movement using conveyor, automated guided vehicles (AGVs), or autonomous mobile robots (AMRs) are only few instances of advancements in this regard [12, 13].

Although such transition within library embraces several industrial and technical challenges, this triggers a research agenda for academia to investigate the technological potentials lying in the scope of material handling. In this regard, there are few instances of effort from researchers aiming at uplifting the digitalization level in li-

brary, such as using radio frequency identification (RFID) for tracking library materials, autonomous manipulation of books, and so forth [14, 15]. This area, however, requires more attention from researchers, given the fact that libraries still suffer from lack of technological solutions. For example, Trondheim Public Library of Norway, situated in a city with numerous academic visitors, i.e., students, researchers, professors, etc., encounter several operational challenges due to ineffective available solutions, which affirms solid essence of technological improvements, even though this entity benefits from some useful technologies, e.g., RFID, sorting machine, etc.

Hence, to address this gap, this study primarily puts forward to conduct a thorough investigation of feasible technological and digital solutions that lead to the improvement of material handling processes in libraries, as the key role within the library operations. To satisfy this objective, it is deemed necessary to identify the logistics related processes involved in library operations, which is addressed by field observations and technical meetings with librarians of Trondheim Public Library, as the case study. Secondly, we benefit from the principles of systematic literature review to access a broad range of documents and collect a list of available solutions from papers discussing technological advancements of intralogistics and material handling. Ultimately, and through focus group discussions with librarians and authors [16], different dimensions of adopting the identified technologies are benchmarked across a set of key performance indicators (KPIs).

The remainder of this paper is organized as follows. Section 2 assesses operations in the library to address the initial goal of this paper with accordance to the concept of "input-transformation-output" processes, which is followed by a background study of technological advancements of intralogistics and material handling. In association with evaluation of technological potentials of library intralogistics and material handling, Section 3 elaborates the research method regarding, including problem formulation, document search process, and analysis approach. Section 4 introduces the collected list of technologies, and sheds light on the feasibility of the identified technological and digital solutions. Section 5 concludes the paper.

2 Background Study

2.1 Operations in Library

Operations in all businesses and organizations are in charge of producing goods and/or services in order to fulfil the customers' demands. The goal of operations is to add value to the inputs during the transformation process and create outputs which are goods or services. Organizations, regardless of their product/service, share some common characteristics and benefit from a fundamental principle in relation to their operations, known as 'input-transformation-output' model [7, 8]. According to this model, *outputs* are recognized as the ultimate products or services of their associated operations, which are generated through a *transformation* process (storing, transporting, repairing, etc.) by using the essential *inputs* (capital, labor, information, etc.) [5]. **Inputs**, in this regard, constitute of 'transforming' and 'transformed' resources. The transforming resources refer to, but not limited, facilities and staff that act upon the

transformed resources which are usually a mixture of materials, information, and customers [7]. **Transformation** is determined by the types of utilized resources, and it majorly involves three sorts of processes [8]: *material* processing, *information* processing, and *customer* processing. The former is in the scopes of logistics operations which transfers materials within the processes, and it is associated with the physical shape, location, and storage of material. The latter, unlike material processing, includes informational and possession transformation which implies the transformation of data, e.g., reports, booking information, etc., as well as the alteration of possession status, be it a good, service, or property. The last one differs according to the type of organization and refers to various services delivered to customers, ranging from physiological to psychological transformation of the customer. **Outputs** is the ultimate element/process that represents the final product or service provided by the enterprise aiming at satisfying the customer's demand.

Library is a non-profitable organization, which could be studied according to the explained model similarly to other sorts of organizations. In this regard, and for better perception of this concept, Trondheim Public Library of Norway is opted as the case study to help with identifying the key operations, and their respective inputs, transformation processes, and outputs. This library has one main building which is served by 8 branches. It owns 430,000 copies of books and other media collections and contributes to launching 1,500 events per annum. In addition to lending diverse materials, it offers variety of services such as language café, assistance with basic computer needs, printing and scanning of document, and so forth [17]. The primary data and information are collected through in-field observations and structured meetings with librarians. This leads to the identification of library operations and intralogistics related processes as one of the objectives in this study. For the sake of generalization, and through comparison with extant literature, the findings of this stage are put into iterative and critical discussions with librarians and academicians.

Operations in library are influenced by the materials and services they offer, which leads to a wide range of variation. However, some operations are recognized as generic and may be typically performed in any library; making materials available, organizing events, providing services, acquiring materials, just to name a few. While satisfied patron, available object, and organized events are relatively the dominant *outputs* of the library operations, a higher range of variation has been discovered pertaining to *inputs* and *transformation processes*. For instance, 'making a material available for patrons' is a dominant operation that addresses only one output, which is satisfied patron, but it consists of various transformation processes, i.e., moving, sorting, storing, distributing, which are triggered by the following inputs: staff, waiting patron, information, facilities, material. Another example is 'organizing events', which is supposed to deliver an organized event as the output, while embracing several transformation processes, e.g., analyzing information, acquiring required materials, moving of materials, etc., using several forms of inputs, i.e., scheduled event, facilities, staff, and waiting patrons. It is noteworthy to mention, that the same approach is applied for other identified operations in order to capture and articulate their associated inputs, transformation processes, and outputs.

The overall perspective of the ‘transformation processes’ depicted that it embraces three processes, in which the material processing is particularly comparable to logistics operations. This is majorly observed through processes such as moving, sorting, controlling, and storing of materials, which signifies a strong link with intralogistics and material handling. This implies that material handling is one of the dominant processes of the library operations and serves substantial potentials of improvement in this environment. As a result, this study puts forward to investigate the improvement possibilities at a higher abstraction level, and the remainder of this study sheds light on intralogistics operations and material handling to pave the way for technological improvements of library operations.

2.2 Intralogistics and Material Handling

Logistics operations, with respect to the organizational boundaries, are performed internally and externally [18]. The internal movement of materials between different logistics nodes within an organization is known as intralogistics, and majorly constitutes of organization, control, execution, and optimization of internal material flows [9, 11]. The main objective of intralogistics is exploiting appropriate tools and methods with adequate quantity and quality at the right time and location with minimal efforts and costs [19]. Given the correlation between intralogistics and material handling, this goal is realized through the selection of correct equipment. As outlined earlier, material handling is concerned with the movement, protection, storage, and control of items through several phases, i.e., manufacturing, warehousing, distribution, consumption and disposal [10]. From operational standpoint, intralogistics operations, particularly according to the material handling equipment, are accomplished in three forms [20]: manual , semi-automated, and automated. In this regard, one study surrounding the material handling equipment, suggests four taxonomies [10]: transport equipment, positioning equipment, unity load formation equipment, storage equipment, identification and control equipment.

According to the complexity of logistics operations, the technological and digital solutions has served organization with promising opportunities over the last couple of decades to overcome the challenges involved in material handling processes [9]. In this regard, an increasing demand to semi-automated and automated material handling equipment is observed in organizations to combat the difficulties associated with efficient, responsive, consistent, and predictable operations. As a result of such improvement, a system is expected to experience reduction in operation time and expenses, and elimination of repetitive or unsafe manual tasks for labor [10]. By leveraging the technological improvement of material handling, organizations are nowadays confronting a wide range of alternatives, such as AGVs, electronic monorail systems (EMS), pallet conveyors, rail-guided vehicles (RGV), stacker cranes, and so forth [11]. In this regard, studies reveal that various types of organizations, i.e., hospitals, airports, etc., that cope with intralogistics operations, have benefited from available technologies. In one study the application of AMRs within hospital is investigated in order to assess the applicability of this approach in improving material handling in terms of flexibility, productivity, quality/service, and costs [21]. The results indicate

that automated material handling reduces costs, time, and staff member's responsibilities. Another study highlights the essence of RFID technology in providing more efficient services at airport. In this regard, an efficient controller-based luggage tracking system was proposed with the help of RFID, and this platform led to the improvement of controlling and monitoring of transportation which can serve both travelers and staff [22].

Intralogistics and material handling serve a broad range of library operations and have a considerable impact on the library's performance, yet they are majorly performed manually. Needless to note, that manual material handling is labor intensive which incurs a significant cost, and thus, it has a high priority in system automation [23]. This evokes lack of studies related to technological improvement of library operations, and as a result, this study sets the objective to address this gap. For this purpose, as highlighted in section 1, a thorough review study is accomplished in the remainder of this paper to discover and collect the technological solutions that has been investigated by other researchers or utilized by other organizations, in the context of material handling. This list, is thereafter, tailored to the library operations according to the scope of this study, and a feasibility examination enriches this goal.

3 Methodology

The investigation of library operations through on-site observation of the Trondheim Public Library, elucidated the link between transformation processes and intralogistics operations. This conceptual connection signifies the remarkable potentials of improving the library operations via upbuilding the identified processes, by exploiting the recent technological advancements in the realm of intralogistics, and particularly material handling. Thus, it is deemed essential to conduct a review of the extant literature and technical documents to articulate the favorable technological and digital solutions. To that purpose, this section elaborates on the employed methodology that aims for not only the systematic collection and analysis of the information, but also for feasibility assessment of the identified technologies.

The procedures of conducting a literature review vary on the basis of the study objectives. However, the collection of research items and scientific materials is a compulsory step which is inevitably involved in all review studies. In addition, the synthesis of information in a review study is intrinsically prone to bias assessment in the absence of rigorous methodology, and in this regard, systematic literature review (SLR) serves as a promising approach to address such challenges [24]. From methodological perspective, SLR serves as a framework for researchers to conduct a systematic and rigorous review study through a set of comprehensive steps [25]. It is worthwhile to mention, that although the overall approach towards conducting a literature review study is determined by the study's purpose, the underlying principles of SLR are accommodated to the scopes of all sorts of review studies [26]. Given the scarcity of scientific contributions pertaining to the overall goal of this study, a comprehensive document retrieval is inevitably significant. Furthermore, it is particularly vital to derive the required information systematically to facilitate a reliable and efficient

assessment of the collected list of technologies. To that aim, and in order to best utilize the principles of SLR according to the scopes of this study, the following steps are essential [25-27]: problem formulation, literature search and screening, and content analysis.

1. **Problem formulation**. This is the primary step and relates to formulating the problem(s) that reflect the concern of the review study. According to the objectives set in this paper, the main problem in this context is defined as '*which technological and digital solutions are available in intralogistics?*'. This will be further scoped within the library sector thanks to the library operations defined in the previous section.

2. **Literature Search and Screening**. This stage incorporates a systematic and rigorous approach to collect the relevant materials and research items with accordance to the formulated problem. The literature search is significantly dependent on the identified list of keywords which are specified according to the devised research question. In this regard, the following keywords are considered as the basis of online search: 'logistics', 'technolog*', and 'material handling'. The asterisk (*) symbol is used for 'technology' to include its terminological variations, i.e., plural form, adverb or adjective, etc., which is not the same for other keywords due to the fact that they are common and accepted terms referring to a practical domain. It is also essential to place "material handling" between two double quotations ("") to search and retrieve *exact matches*. Given three groups of keywords, the Boolean operators 'AND' is used to combine them in the correct conceptual manner, and the searching process scans the *title*, *abstract*, and *list of keywords* associated with each document. The online database of Scopus is targeted for accomplishment of the search process, which serves academia as a rich source of documents. The entire search process was performed on 26th March 2023, and it yielded 442 records. The primarily retrieved items are narrowed down by applying appropriate filters to exclude less- or non-relevant items; the language is set to 'English' to target documents at an international scale; the search horizon is confined to the interval of the last 10 years which was a period with extensive technological and digital improvements; document types are filtered to journal articles and conference proceedings in the subject area of 'engineering' to ensure access to a broad scale of relative documents. The aforementioned filters reduce the initial results to 95 items. To ensure the exclusion of items with weak conceptual link to the research goal, a screening process is performed, and commences with *first screening* which includes the assessment of titles, abstracts, and keywords of each document. Thereafter, and during the *second screening*, full content of the remainder documents is skimmed, to ensure high reliability in using the retrieved materials, which reduces the list of items to 43 records. Moreover, the papers associated with technologies that have lack of general suitability to the library environment, e.g., electric forklift, pallet trucks, etc., are excluded in this stage which results in 29 records, as the ultimate list of papers. Given the scarcity of academic documents according to the concern of this paper, we also incorporate some grey literature to enrich the available documents and broaden the list of possible solutions with respect to the objective of this paper. The term "grey literature" refers to documents published outside the

conventional publishing and distribution channels, and it refers to a variety of forms, such as report, newsletter, working papers, official government document, policy document, and so forth [28]. Grey literature are accessible through online databases, e.g., OpenGrey, or by handsearching [29]. For this study, we opted the handsearching strategy to collect grey literature which resulted in 18 documents. To be more precise, this is realized through manual investigation of relevant documents, and thanks to the advancement of internet-based solutions, the search engine of Google is utilized to find relevant documents, including the list of available suppliers that provide technological and digital solutions for different industries. The aggregated list of references which have been studied in this regard, accounted as 47 documents, is available at the following link: https://drive.google.com/file/d/1O2Qml-BgWnlMvolOFtx0_wNbYHkfJ-ur/view?usp=sharing.

3. **Content analysis**. This stage refers to the synthesis of information collected from the final list of documents. In this regard, the main goal is to identify the digital technologies that have favored intralogistics operations and material handling processes in organizations. Hence, we primarily seek to produce a comprehensive list of technologies that are potentially beneficial to the material handling processes in library. Afterwards, a list of KPIs is used to benchmark the feasibility of the identified technologies across the environment and operations of the library. To this aim, and through the involvement of academic experts and librarians, we put this concern into several technical discussions, according to the focus group technique [16], to ensure a rigorous and unbiased assessment of technologies against the specified KPIs.

4 Results and Discussion

According to the described technological lag in material processing of library operations, which falls into the scope of intralogistics and material handling, this paper put forward to investigate the practical and beneficial technologies that potentially contribute to the improvement of the library operations. To approach this goal, a preliminary and extensive list of relevant technologies was generated according to the documents that were collected with the help of SLR steps, as explained in section 3. In this regard, this section primarily presents the list of identified technologies across their applicability towards the major material handling processes within the library. This phase is then followed by an assessment study to benchmark the feasibility of highlighted solutions against a set of specified KPIs.

4.1 Technological and Digital Solutions for Library Intralogistics

Through field observations and iterative technical discussions with library staff, and according to the intralogistics elements, four major categories of processes are considered in this regard: moving, sorting, storing, and controlling. Moving majorly refers to the transportation of items between two points. While this is particularly confined to the physical position and movement of items, sorting serves the material han-

dling processes with similar application. However, the core mission of sorting is increasing the flexibility by transferring individual items to distinct routes. Storing has broad applications in the library, ranging from archiving and long-term shelving to temporary stock keeping of items. Controlling has a surveillance function that not only incorporates several activities, but also is strikingly significant to efficient operation of other processes through information sharing and data transmission.

The identified technologies, which are derived from the collected documents, are investigated based on their corresponding functions across the outlined material handling processes. Therefore, Table 1 represents the functionality profile of each technology which is determined by its practice pertinent to the specified dimensions of material handling. It is worthwhile to mention, that the boundaries between these four processes are sufficiently clear; however, distinction between the applications of each technology with accordance to this taxonomy is sometimes blurry. Thus, it is vital to launch technical group discussions with academicians and practitioners to better address this issue. In this context, it is emphasized that each technology is not restricted to *only* one aspect of material handling, even though it is recognized with a particular and prominent application. For instance, AGV, AMR, and Drone are amongst the advanced multi-functional technologies that assist material handling processes from various perspectives. In the scope of this paper, as demonstrated in Table 1, the outlined technologies fulfil the required criteria to function within the framework of all four identified processes of material handling.

Table 1. Feasible technologies contributing to material handling processes in library.

Solutions	Material Handling Process			
	Moving	Sorting	Storing	Controlling
AGV	✓	✓	✓	✓
AMR	✓	✓	✓	✓
Drone	✓	✓	✓	✓
Ergonomic Bin	✓		✓	
Conveyor / Rail Guided	✓	✓		
Elevator / Vertical Lift	✓			
Sorting Machine	✓	✓		✓
Industrial Robot for Pick and Place		✓	✓	
Collaborative Robot for Pick and Place	✓	✓	✓	✓
ASRS / SBSRS / VLM			✓	✓
Machine Vision		✓		✓
RFID	✓	✓	✓	✓
Barcode / QR Code	✓	✓	✓	✓
Self-Service Kiosk		✓		✓
Book Vending Machine		✓	✓	✓
Intelligent Return Shelf	✓	✓		✓

AGVs and AMRs have favored various shop floor activities and productions systems to increase the efficiency and flexibility of transportation [30, 31]. Solutions of such form, however, are not limited and, in this regard, drone is repeatedly outlined as a beneficial technology. Ergonomic bin is another novel solution of book movement,

but more importantly, it facilitates an intelligent and efficient collaboration with human in favor of an ergonomic accomplishment of pick-and-place tasks [32]. Conveyor/rail guided, and elevator are stationary equipment for, respectively, horizontal and vertical movement of items which are amongst the most recognizable equipment in this context [33]. It is noteworthy to highlight, that sorting machine has a similar application, however, it is majorly responsible for specifying further paths for items which ensures higher flexibility [34]. Industrial robots that are suitable for light-to-medium weight load, have a strong profile for library application that perform repetitive tasks with high accuracy and flexibility. To add more intelligence and resilience, the benefits of collaborative robots are extensively discussed, given interaction potentials with human and environment. ASRS and shuttle-based storage and retrieval system (SBSRS), as well as vertical lift modules (VLM), are advanced technologies of shelving and storing which are equipped with flexible robotic solutions. Machine vision is a visual detection technology that serves as a sensor with advanced image recognition capabilities to transmit necessary data and contributes to decision making processes. RFID is undoubtedly amongst the most well-known technologies that has been applied in various industries and organizations. Given the particular capabilities of information sharing associated with RFID, it serves as versatile technology that facilitate more efficient and accurate accomplishment of several processes and activities. According to such property, barcode and quick response (QR) code are other means which provide similar possibilities and equip operations with an efficient and flexible data sharing platform. As also highlighted, such technologies are supportive solutions that improve the efficiency and flexibility profile of other processes, e.g., inventory control, sorting of books, etc. Self-service kiosk and book vending machines are innovative alternatives that support offline book borrow and retrieval without the intervention of library staff. Technologies of this form have benefited various operations across different organizations that not only increase the process efficiency, but also improves responsiveness through elimination of several waste factors, such as staff unavailability, waiting time in queues for patrons, and so forth. In this context, intelligent return shelf is another solution that in combination with other technologies, e.g., sorting machines, conveyor, etc., enables flexible storage and retrieval of items by direct intervention of patrons [35].

4.2 Assessment of Technologies: Operational Framework

The list of feasible technologies (see Table 1) demonstrated a wide range of solutions with promising application to material handling processes in library. Although the profile of each technology was assessed against four categories of processes, it is deemed essential to evaluate each solution from operational perspective. According to the digitalization objective, four major KPIs were identified through technical discussions between authors and various librarians: smartness, speed of operation, cost, quality/service. The smartness not only reflects the degree of automation pertaining to the technology of interest, but also aims to highlight the level of intelligence. Productivity is inevitably a vital criterion to any operation, and it impacts the overall productivity, efficiency, and responsiveness of operations. Given budgetary constraints at

any organizations, the cost of purchasing a technology is a crucial element towards the technological improvements. It is worthwhile to highlight, that the operational and maintenance expenses are another critical cost factors which are embedded within this KPI, as well. Last but not least, is quality/service which majorly aims to capture the metrics of accuracy, reliability, and safety.

To best satisfy the evaluation goal, and more importantly to minimize the element of bias assessment, we arranged several sessions of technical discussion, individual- and group-based, with librarians and authors to rate each technology against the outlined KPIs. For the assessment purpose, a three-tier scale—low, medium, and high—shapes the fundaments of assessment such that each KPI may adopt one value of this spectrum. As depicted in Figure 1, the horizontal axis represents the identified technologies (identical to Table 1) and the vertical axis bases the ground for rating each technology across the identified KPIs. The bar lines associated with each technology represent the KPIs, which are distinguished by colors, i.e., blue, black, green, and orange, and respectively (from left to right) associated with smartness, productivity, cost, and quality/service. In this regard, the length of each bar demonstrates the value of the KPI as opposed to the corresponding technology, which may adopt only three values. Such assessment profile of the identified digital solutions assists libraries in decision-making processes which are based on the technology adoption. In this regard, it is possible to conduct pair-wised comparisons between solutions with similar practices in order to evaluate the different dimensions of incorporating each technology into the library environment. For instance, according to Figure 1, the smartness and productivity of AMR (high) stands over AGV (medium), although it is a more expensive solution. This implies a trade-off between cost and other KPIs and demands corresponding decision, which is potentially linked to the individual preferences and criteria of libraries and there is no generic or optimal answer to that. The similar attitude applies to the interpretation and inferences pertaining to other technologies represented in Figure 1, and the ultimate decision regarding the selection and adoption of each technology is dependent on various criteria that potential varies across different libraries.

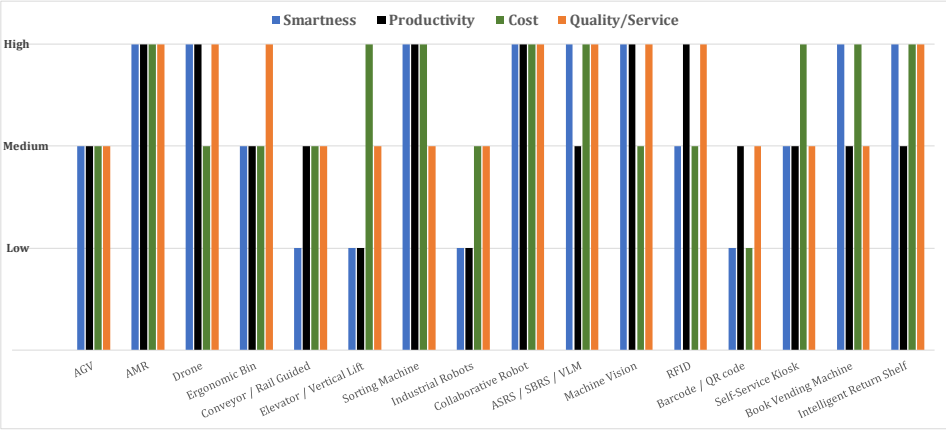

Figure 1. The evaluation of technologies against the identified KPIs.

It is also of significance to mention, ergonomic issues and safety measures within library are of substantial importance and they must be considered prior to adoption of any technology. These measures are even intensified given the dense presence of patrons in the library environment, and digital solutions are supposed to comply with such condition. Furthermore, the application of some technologies requires particular structural and physical conditions which restrict their integration with library and would vary across different environments due to individual characteristics of libraries. For instance, the ceiling height is an important criterion for the application of ASRS and SBSRS. Even though it was not particularly listed, internet of things (IoT) and cloud computing are strikingly important to facilitate the application and integration of several technologies discussed in this paper. As a matter of fact, synchronizing the technologies for accomplishment of various scenarios is particularly significant to efficient operation of library and increasing the automation profile of material handling processes. This is realized through the possibility of real-time information sharing, online communication between devices and equipment, as well as storage and usage of data.

5 Conclusion

Libraries are service-oriented organizations with no specific revenue-generation goal. According to the advancement and expansion of societies, libraries offer variety of services to keep up with societal demands and this require more efforts, compared to the conventional manner of administration. A comparison between libraries and other organizations reveals that there is a significant potential in improving the library operations by taking the advantage of technological and digital solutions, and we conducted an exploratory study to shed light on this issue. To address this technological lag, the library operations were articulated according to ‘input-transformation-output’ model and using the case study of Trondheim Public Library. This evaluation depicted that transformation process serves significant potential of technological improvement, and it is dominated by material processing. Given the solid link between material processing and intralogistics, this study navigated through previous research works to identify solutions that have benefited material handling processes and satisfy the outlined technological gap in library operations.

The collected list of technologies covered a wide range of solutions which were then narrowed down in order to accommodate the list for library operations. To better highlight the functionality of each technology exists in the ultimate list, the material handling processing was broken into four sub processes, including moving, sorting, storing, and controlling. This assessment creates a functionality profile for each technology and paves the way for adopting the technological solutions in response to the specific areas of material processing that require improvement. In addition, four KPIs were specified, and the operational contribution of each technology were examined according to a qualitative scale: low, medium, and high. This analysis attempts to facilitate a pair-wise comparison between technologies with similar application, as well as expanding the perspective of selecting the suitable technology. The results,

however, are not conclusive due to the unlimited advancements of technologies in this digital era. For instance, IoT and cloud computing are vital digital solutions that are significant to increase automation and establish integration throughout library. In addition, adoption of technologies requires further attention to ergonomic, safety, and physical limitations that could be specific in any library. In general, this study put forward to assist libraries in uplifting their technological profile with the aim of improving the material processing efficiency. The findings of this study are at a high abstraction level for the benefit of general application. However, and according to the examinations provided in this paper, it is of advantage to perform a strategic fit analysis to discover the technical barriers, as well as required infrastructural conditions, in different scenarios. According to the scope of this study, the identified technologies were analyzed individually throughout examinations; however, it is advantageous to evaluate the possibilities and positive potentials of coupling the explained solutions.

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