SWADESHI MICROPROCESSOR CHALLENGE

Smart automated storage-retrieval system

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Detail Proposal Form - Ideate Stage of Quarter Finals

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Industrial Automation using smart Automatic Storage and Retrieval System

The SmASRS system aims to provide a more accessible and useful warehouse automation system that is capable of managing inventory, placing and picking objects, and being controlled remotely. The project is targeted specifically for the Indian market, where issues such as small scale of operation, non-standard stocking techniques and employee errors plague the industry.

Problems such as poor inventory management, limited employable hours from workers, dangers of operating power tools and forklifts in the warehouse are targeted by this system. It is a modular approach to managing shelf space and keeping track of items in the warehouse. It can be employed non-stop for long hours, and requires very little to no human intervention. In addition, this system also can be introduced to warehouses in phases, and does not require extreme makeover of existing infrastructure.

The low cost of implementation and added advantage of data processing using IOT, AI and Data Analytics make the SmASRS a highly potential investment for the rapidly expanding Indian warehousing industry.

Current problems with Indian warehousing

- **Lack of Inventory Data Analytics and Poor Management:**
    - Current system of inventory management includes feeding of data manually into a database, wherein data is analysed further by a person or predefined methods and then this data is utilized to optimisation of storage, this is time consuming, involves manual intervention and always carries a risk of an error.
    - Periodic Audits are done to take stock and tally inventory for mismatch. This process is done manually and takes a lot of time.
    - Poor Analysis or Incomplete analysis of data collected from Manual Inventories
    - Difficult to Implement optimisation strategies
    - Lack of speedy retrieval or storage of goods
- **Storage mismanagement, sub-optimal use of space:**
    - Due to inefficient storage practices the total inventory per unit area is low and there is a delay in locating items
    - Dense Packing of Shelves not possible because of clearance and space requirements for forklifts to go through and inability of high stacking
- **Unavailability of generic cost-effective automation solutions that can be implemented without breaking apart existing infrastructure.**
- Any existing automation solutions are not very cost-effective and require the existing infrastructure to be heavily modified.
- Safety and occupational hazards that accompany the handling of goods and use of forklifts in warehouses.
- Product loss due to:
    - Wear and tear due to long storage periods
    - Damage of fragile goods due to human errors
    - theft and untracked inventory

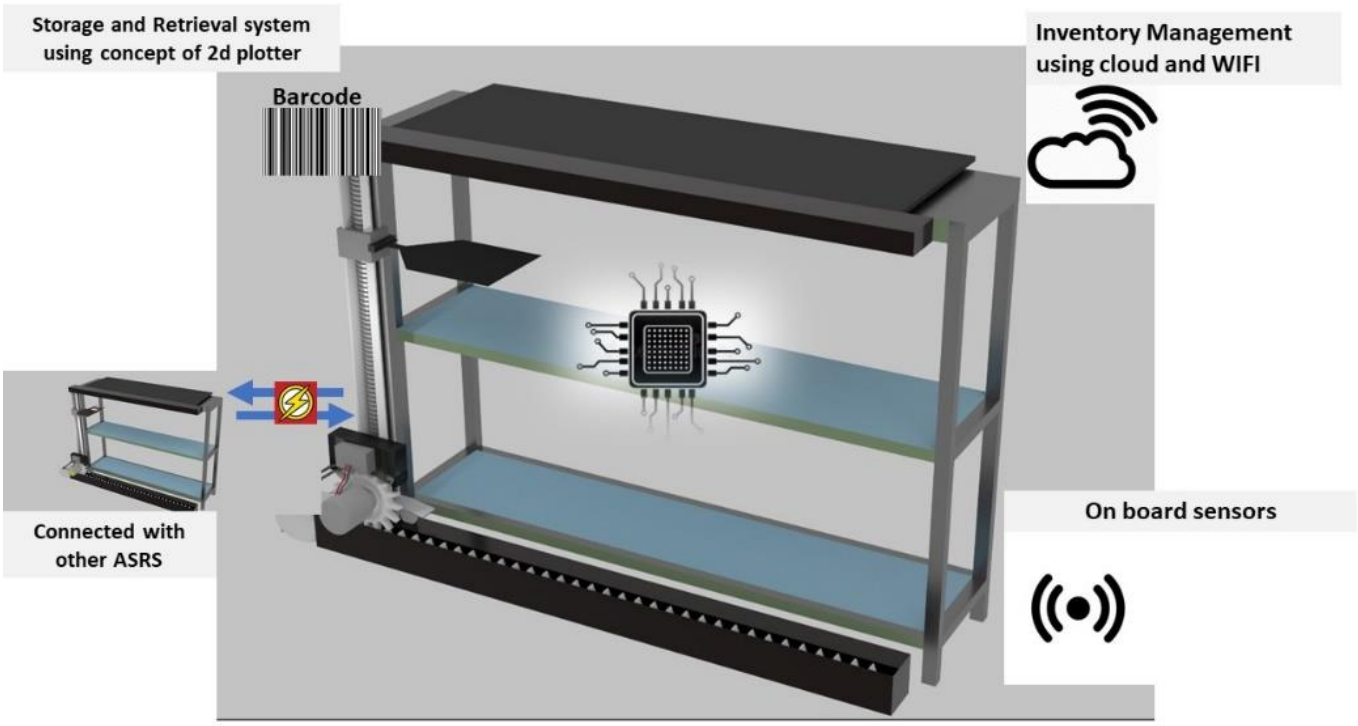
Smart automated storage-retrieval system

This particular SmASRS system is a simple 2-D plotter mechanism with enhanced movement along another axis which helps in achieving a nearly 6-DOF workspace for our mechanism. With the rack & pinion along with complementary motors we expect to get complete and stable control to reach any point within a plane.

Control algorithms like multiple 3-dof PID control laws and DLS will be applied to ensure complete coordinate convergence. Furthermore, our X-axis length and Y-axis length are completely discretized from the mechanical components we've chosen to implement motion along their path, which allows for easy setpoint commands in the form of rotations we would want a motor to execute to reach that particular point.

All the items are tracked using a bar-code scanner which ensures all the scanned data can be correctly utilized by the data processing system that helps in increasing efficiency and reducing fulfilment time.

Our primary mode of communication between different modules and to the main server would be in the form of Wi-Fi, due to ease of implementation. This version of SmASRS also provides the freedom to implement any type of sensor with the system and record particular data if the warehouse wishes so, as long as it can be interfaced with the indigenous processor.

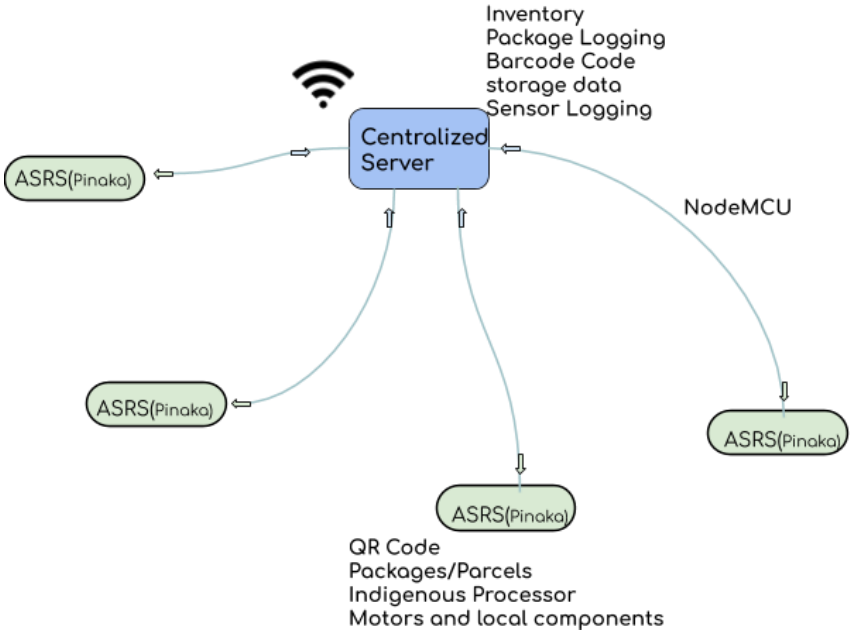


Electrical systems

Each Module will have a dedicated **Pinaka** processor to it which will be responsible for all the computation, planning algorithms &motor control. The **Pinaka** module will also be responsible for communicating to the central node over wi-fi and transmit the bar-code data scanned by it

Communication and interfacing

Our aim is to deploy a centralized star topology network where the central node will be the server/ host computers of the workshop which would be able to access Inventory updates, item requests, BAR tagging commands and sensor logs that will be achieved from each SmASRS module over wi-fi using Esp8266 modules



Power

The electronics of each SmASRS module comes with a custom made PDB accompanied by appropriate BMS. Since SmASRS isn't restricted to the type of warehouses , additional sensors or functionalities can be added depending on what the buyer wants .Each module powered by an AC power supply ,furthermore, each SMASRS has its appropriate AC/DC converters and then a flexible power distribution system which allows any sub-module to get actuated when required. The wiring from components and power supplied is well coated, sorted and ensured with a high degree of protection so that under no circumstance will the parcel/boxes.

Motors

The basic layout is a motor responsible for X-manoeuvres which would be a high torque, moderate RPM motor to gain precision over how it is moving and also have the capability to flexibly handle loads within a particular weight range. SMASRS uses two more motors, one for rotating the screw responsible for movement along the Y-axis and one for a linear actuation system responsible for moving the tray along the X-axis. Both of which are expected to be moderate RPM and higher torque motors but they would require considerably less torque than the motor in the rack and pinion arrangement.

Bar code

The main goal of our designed AS/RS system, is to perform real-time tracking using Bar code. In such an application, the stored products/packets have unique bar codes, thus their location coordinates are known to the system as they are assigned to them by the swadeshi microprocessor. The bar code scanner knows the positions of all stored products equipped with bar code; therefore, it enables real-time storage/retrieval operations. The AS/RS system tasks include design, physical construction and control.

Data processing

All the data processing is done at the central node which ensures effective utilization of data:

- **Automated Planogram Design:** By analysing the demand, time of retrieval and time taken to transport goods from a shelf to a truck, the system can generate a planogram, to store goods more appropriately, with ideal locations thus increasing speed and efficiency. Since the system is automated this planogram can updated more frequently than a manual one can be due the systems quick adaptability.

- **Priority Based Storage:** Using this will enable the system to store goods with higher demand closer to the output side of the shelf and on lower ranks, while goods with lower demand towards the end and higher ranks, what this does is, that the retrieval and storage time of high demand goods is reduced thus bringing down the average access time of the system significantly, this also helps bring down the wear and tear of the mechanical system.

- **Perishability Prevention:** This system will use a FIFO architecture, where in the system will intelligently retrieve the product that was stored first and useable for the intended purpose thus preventing the item from perishing or going bad just due to siting around. In the case of old stock, the system sends out an alert to plan new selling strategies to prevent loss

- **Automated Ordering:** While keeping the track of inventory the consumers can set conditions for various types of alerts for each good, for e.g. By analysing the consumer demand and depending on available stock the production and future products required can be predicted to optimise inventory

- **Inventory optimization:** When using intelligent machines to store and retrieve goods, the space requirements and clearance requirements get reduced drastically as compared to usage of manual machines like forklifts, and thus increasing storage density and increasing a company's utilization value per square inch (unit).

Mechanical systems

The SmASRS is aimed to be a complete storage and retrieval system and thus the mechanism needs to allow for accessibility in the entire rack. The best part about this version of warehouse automation is that it won't require a complete ecosystem revamp, but it will adapt to the existing architecture/ layout of how that warehouse is. Moreover, depending on what kind of environment is being targeted SmASRS is modular enough to integrate appropriate sensors and mechanisms with the way it's designed.

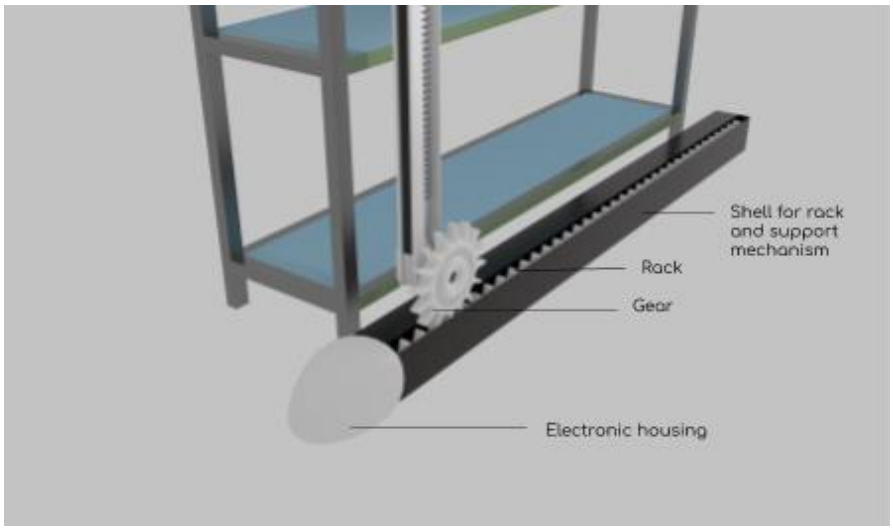
The components which broadly make up the assembly:

- **X-Manoeuvre mechanism**
- **X-Manoeuvre mechanism**
- **Tray/Holding mechanism**

The main component responsible for carrying boxes/items will be a small-scale forklift which will allow boxes within a range of dimensions to be transported easily. The system will consist of a 2-D plotting mechanism to traverse anywhere in the X and Y axis by using the **X and Y Manoeuvre mechanisms** in collaboration, however the tray will have the freedom to traverse the Z-axis as well making the entire rack area to be accessible.

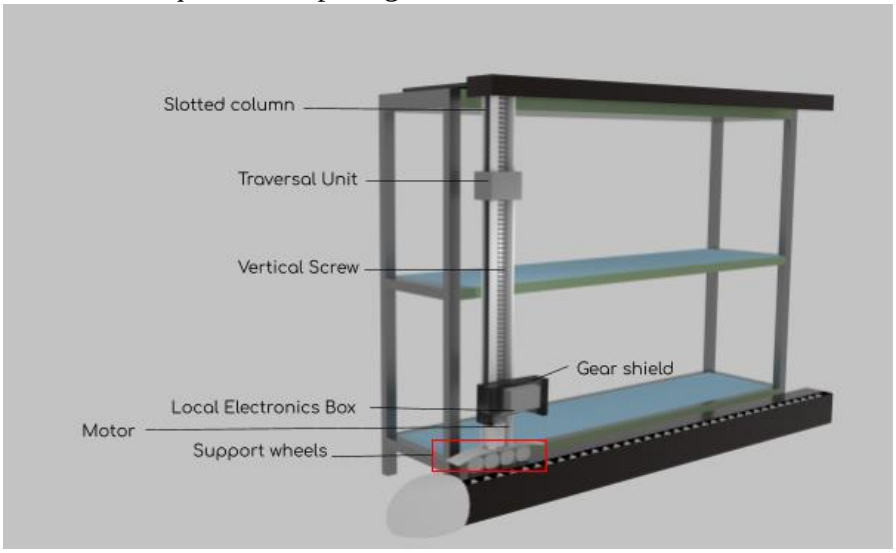
X-Manoeuvre mechanism

The tray will be moved along the X-Axis using a simple rack and pinion arrangement to which the Y-Axis arrangement will be attached from the centre of the gear module. The top support rail exists solely to provide extra stability to the Y-axis arrangement and also limits the Y mechanism to only translate and removes any tendency of toppling/ any external torque which might cause the vertical rail to topple.
The rail length will be known for the particular shelves and a particular location in X can be reached easily by operating the motor for a particular amount of time. The motor driving the gear attaches itself on the Y-Axis arrangement and traverses along with the gear to simplify mechanical design.
Furthermore, with this approach it can adapt to any warehouse/ existing infrastructure unlike other automating arrangements available.



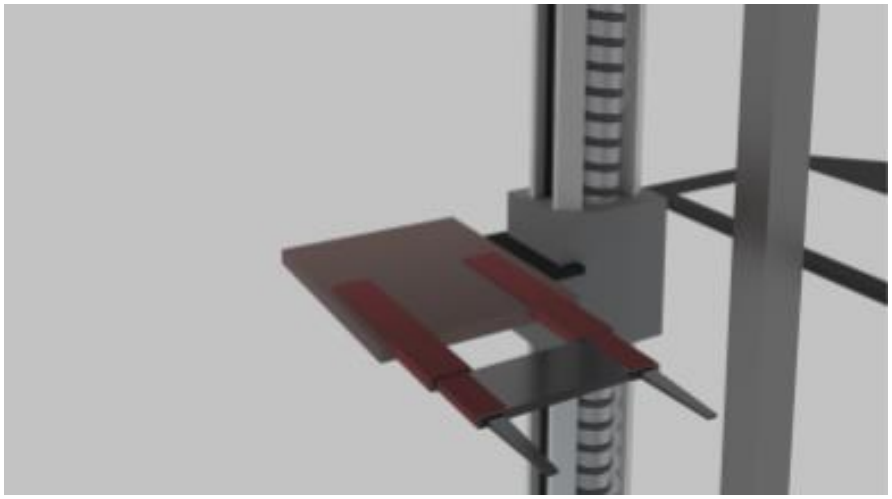
Y-Manoeuvre mechanism

Motion along the Y-axis will be done by a threaded screw powered by a motor at the bottom. The tray is attached to the traversal unit which is a box which houses local electronics and also provides for a stable base structure for the tray. The screw is supported by two columns which have a predefined slot which help impact extra dynamic stability of the traversal unit.
The traversal unit has extrusions which lock in perfectly with these columns. By doing this the traversal unit moves along the Y-axis without inducing a rotational tendency making it very stable.
The screw helps in having infinite points of ‘rest’ for the transversal unit and allow us to operate accurately with the least distance traversed to be equal to the spacing between the threads.



Tray

The tray responsible for loading and retrieving boxes in the shelves will be a small-scale retractable forklift which will allow to operate with boxes within a set of dimensions rather than just one particular type of box making the system completely adaptive to the type of boxes the warehouse deploys.



Automated ecosystem

An automated storage and retrieval system provide an excellent foundation to build on with connectivity at the core. The development of seamlessly meshing machines opens up the possibility to effortlessly scale, repurpose and expand the system. Dividing the entire automated system into repeating units can also help with easy maintenance and inter-connectivity, allowing for the development of a true ‘ecosystem’.

The ecosystem for this project shall namely be built of the following assets:

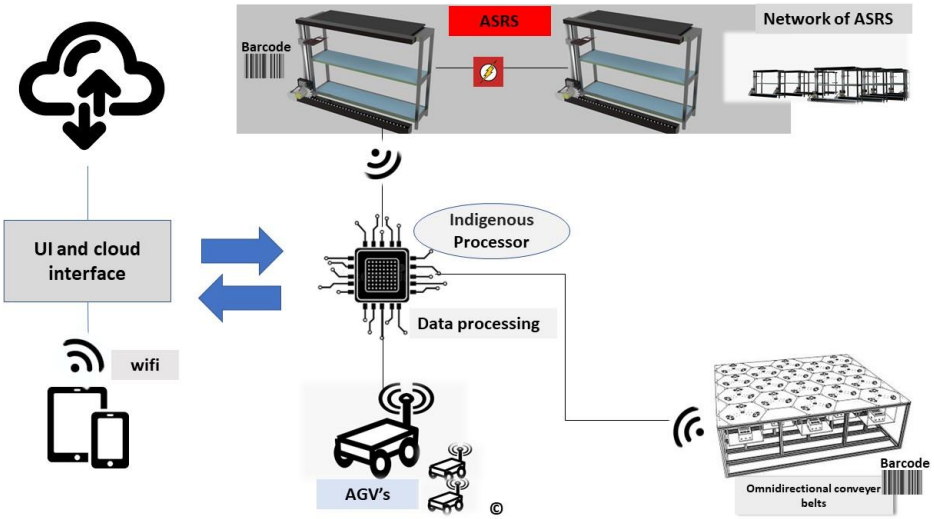
- Individual, repeating AS/RS modules
- Cooperation with other autonomous ground robots
- Robust communication and network connectivity
- Central monitoring and data processing
- Inter-machine synchronisation and coordination

The several advantages of dividing an automated system into several small, repeatable units have been discussed earlier. Building on this, it is also essential to consider the savings in cost and reliability that comes as a result of modularisation. Compliance with various warehouse variables such as floor dimensions, ceiling heights etc shall no longer be an issue with modularisation. Additionally, the failure of a functional unit also shall then only affect a small portion of the entire warehouse. Such a failure, be it electronic or mechanical, when identified, shall make the entire ecosystem aware of the location and implication of the failure, opening up the possibility to operate even without the system being at 100% operational capacity.

The use of standard communication protocols opens up the possibility of highly connected automated systems that communicate effortlessly and make logistics extremely manageable. Owing to the accessible nature of this method of communication, this also opens up the possibility of an ecosystem with the inclusion of warehouse automation floor robots, packaging robots, and even manufacturing in certain situations.

An often-overlooked issue in present day warehouses is the manual method of inventory management. With inter-machine co-operation, it becomes possible to identify the exact item being mobilised with Bar-code based identification. Additionally, relocation and repositioning of objects becomes a possibility for maximising storage space and hence optimising warehouse operations.

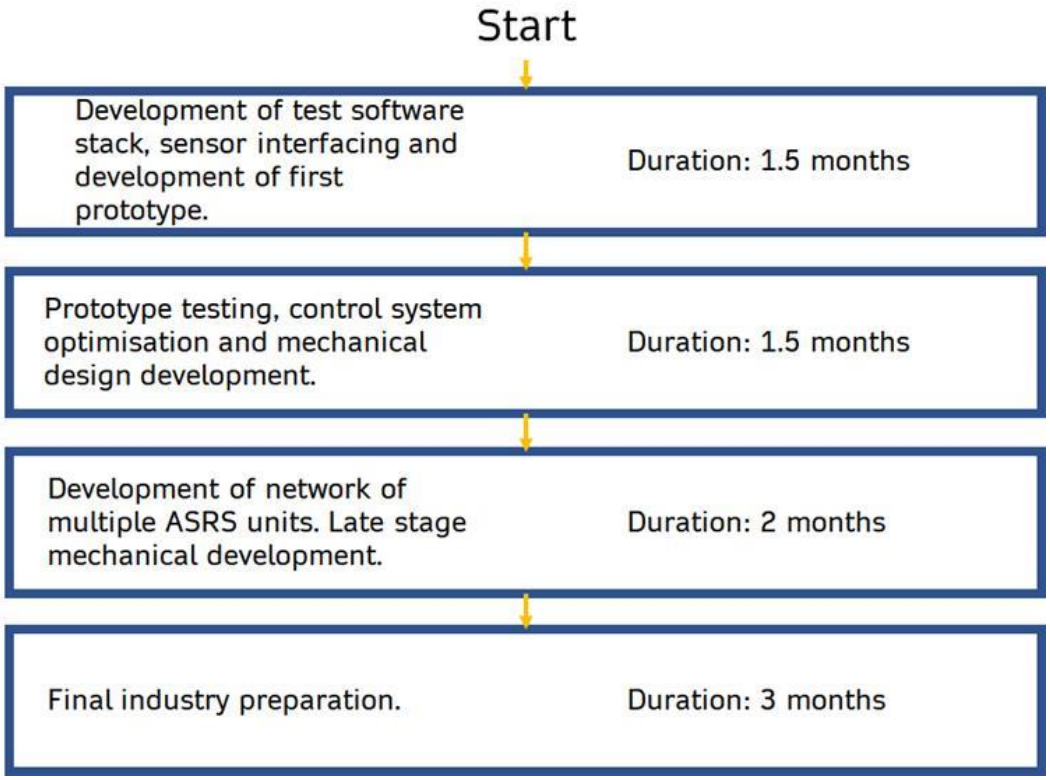
Lastly, every single process being executed can be easily updated to a central monitoring system for easy access by employees and surveillance. The exact location and quantity of each item can be easily accessed to make for a robust, easy to use system that eliminates a lot of issues currently plaguing warehouses.



Preliminary tests

- The conceptual idea of SmASRS was tested by development of a 2D 2-axis plotter. In this test model, various control algorithms like multiple 2-DOF PID control laws were applied to ensure complete coordinate convergence. Various motor drivers were interfaced and tested to make sure that the control of motors is accurately functional, and that current drawn by motors is within permissible limits.
- To test and manage the various functionalities of the system, the STM32F4 microcontroller was used as a processor due to its resemblance to Pinaka.
- Communication with Wi-Fi was tested by interfacing the Node MCU with STM32F4 microcontroller.
- Various versions of the mechanical design were developed to visualise the complex multiple-axis movement of the system and to gain an estimate of weight.

Timeline



Requirement of Equipment

The tentative requirement and quantity of components is as follows:

- High torque low RPM Motors (3)
  - Rack and pinion mechanism for X axis
  - Y axis screw rotation
  - Storage-retrieval tray actuation
- Rack and Pinion Gears for x axis
- Threaded screw and support columns for the Traversal unit along Y axis
- Load bearing beams
- Storage-retrieval tray
- Node MCU for wi-fi communication (1)
- Barcode scanning module (1)
- Power distribution board (1)

Each module is estimated to cost ranging between 30,000-40,000 rupees.

Business Aspects of Innovative Solution

Novelty

Warehouse is a pivotal point in any supply chain and is a multi-billion-dollar industry. With ever-increasing consumption and diversifying manufacturing produce, the industry currently heads very clearly towards specialised automated storage and retrieval systems.

Current SmASRS systems require the setup to be built from ground up and need large warehouse spaces due to the complexity in design and specific shelving requirements provided by the vendor. This results in a high initial investment cost and the tearing down of existing infrastructure. This limits the access to automation for medium and many existing industries.

The Smart Automated storage and retrieval system aims to be installed in existing warehouses with a modular design which makes it both - more adaptable and affordable. Expandable X & Y rails and a tray mechanism allows the system to be implemented in existing warehouses without any modification. It also comes with an optional climate monitoring system that relays information to a central server and can be programmed to perform certain routines based on climate conditions.

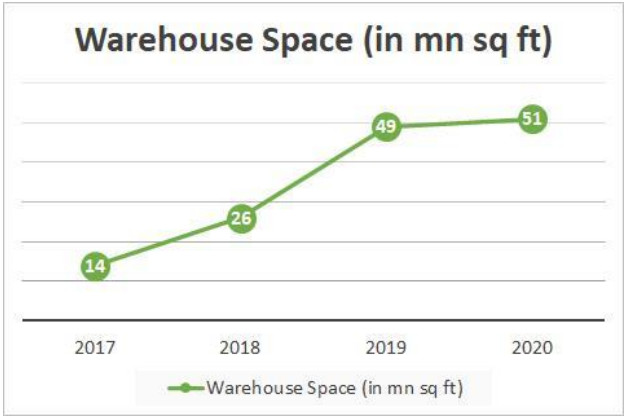
Due to each module being independent of other modules, the entire warehouse does not require to be automated at once and the critical areas can be targeted allowing gradual expansion.

Another advantage the Smart AS/RS has over traditional AS/RS systems is the ability of Data processing Using IoT and AI. The following is achieved using the following methods:

- **Automated Planogram Design**
- **Priority Based Storage**
- **Perishability Prevention**
- **Automated Ordering**
- **Inventory optimization**

Opportunity & Market Feasibility

The warehousing market in India was valued at INR 1,501.2 billion in 2019 and is expected to reach INR 2,821.1 billion by 2024, expanding at a CAGR of ~13.57% during the 2020-2024 period.



The warehousing market is driven by the country's flourishing manufacturing, retail, farming and logistics sectors. Supportive government policies such as establishment of logistic parks and free trade warehouse zones is expected to spur the market growth through 2025. Also, introduction of GST has led to reduction in inventory and turnaround time, which has led to the removal of check points thereby diminishing state boundaries.

Stocking levels to increase

Lean supply chain with a focus on inventory carrying cost has been a key consideration for enterprises. In the COVID-19 19 circumstances, many such businesses, mainly in the essential segment like F&B. groceries, and pharmaceuticals, faced stock-out as raw material sourcing as well as production was disrupted. Learning from the experience, many businesses may look at increasing the level of inventory in the short to medium term.

Warehousing stock and supply

Market	Total warehousing land (Acres)	Total warehousing FSI Potential in mn sq m (mn sq ft)	Existing Stock in mn sq m (mn sq ft)	Vacancy	Development potential in mn sq m (mn sq ft)	Development potential multiple
Mumbai	6,625	15.5 (167)	11.2 (121)	10.7%	4.2 (45)	1.37
NCR	4,178	9.3 (100)	5.3 (57)	13.9%	4 (43)	1.75
Chennai	2,361	4.6 (49)	2.2 (24)	14.7%	2.3 (25)	2.02
Bengaluru	2,210	4.5 (48)	2.3 (25)	29.7%	2.1 (23)	1.89
Pune	1,814	3.9 (42)	2.4 (26)	21.8%	1.5 (16)	1.61
Ahmedabad	1,587	3.4 (37)	1.7 (18)	13.2%	1.8 (19)	2.09
Hyderabad	1,291	2.7 (29)	1.2 (13)	22.4%	1.5 (16)	2.19
Kolkata	1,098	2.6 (28)	2 (21)	20.6%	0.6 (6)	1.29
Total	21,163	46.5 (500)	28.3 (307)	15.5%	18 (193)	1.63

Source: Knight Frank Research
Note: The 'Development Potential Multiple' depicts the total development potential of the warehousing stock in a market, as a multiple of its existing stock.
For example, Total Development Potential Multiple of 1.63 implies that there is potential of 63% more supply from the existing land committed to warehousing

E-commerce to further expand its position as key occupier group

- Even before Covid-19 struck, e-commerce had established itself as a key occupier group. At 14% share in warehouse demand in FY 2018 and 24% in FY 2019, it was second only to the third-party logistics segment. In FY 2020, the sector's share stood at 23%. Other segments like manufacturing, retail, FMCD and FMCG followed in the demand pie.
- Even while the lockdown and movement restrictions served as a temporary propeller for e-commerce sales with the threat perception on the spread of corona virus infection, home delivery service has come to the forefront. During the lockdown, many brick and mortar enterprises adapted to provide the same; however, it is the e-commerce segment which has perfected the art of home delivery Large organized retailers too have ventured into e-commerce in the wake of these developments.
- With restricted mobility, many first-time customers experimented with purchase on e-commerce channels during the lockdown. Many of these customers are likely to turn loyal due to the convenience offered and become permanent customers even after the pandemic ends. Going forward, the fear of coronavirus infection will accelerate adoption of e-commerce purchases as consumers restrict mobility over a short to medium term until there is a cure for the virus.

However, lack of infrastructure is one of the biggest hurdles in the warehousing market in India. India has the lowest amount of warehouses with modern facilities when compared to the rest of the world Additionally, poor road conditions, bad connectivity, inability to handle high traffic density and insufficient air and seaport capacities contribute to the increased cost per transaction in the country's logistics sector.

Furthermore, The Indian warehousing industry is highly fragmented with several unorganized players operating in the market. Organized players in the industry account for only 10% of the total market, whereas around 90% of the warehousing space in the country is controlled by unorganized players who manage small-sized warehouses with less/no mechanization.

Inefficient storage practises, degradation and breakage due to poor storage practices play a major loss in warehouses.

Considering the huge market potential and the Lack of infrastructure and technology in the warehousing sector SmASRS can be a key role player in progressing the Indian warehousing market

- India is known for its advancements in the software and data analytics industry. Technological advancements such as advent of AI, IoT enable the implementation of data processing technologies as mentioned earlier which improve the traditional and inefficient warehousing market in India
- The Indian warehousing industry is highly fragmented with several unorganized players operating in the market. Organized players in the industry account for only 10% of the total market, whereas around 90% of the warehousing space in the country is controlled by unorganized players who manage small-sized warehouses with less/no mechanization. SMASRS can be implemented in small sized existing warehouses at a low initial cost.
- The increased stocking need will lead to a greater demand for warehousing. However, this demand will be served by greater cubic capacity utilization of vertical space rather than mere increase in floor area which can more easily be achieved by SMASRS systems compared to manual methods which involve forklifts or ladders which come with various risk factors.
- Leasing and Operating costs of warehouses for warehouse clusters outside cities are around INR 18-25 per sq-ft a month and it can go upwards of INR 100 per sq-ft a month for in-city warehouses like in Mumbai, by the usage of products like SmASRS, we aim to increase the storage density by at least 2 times effectively cutting down to half of the operating costs

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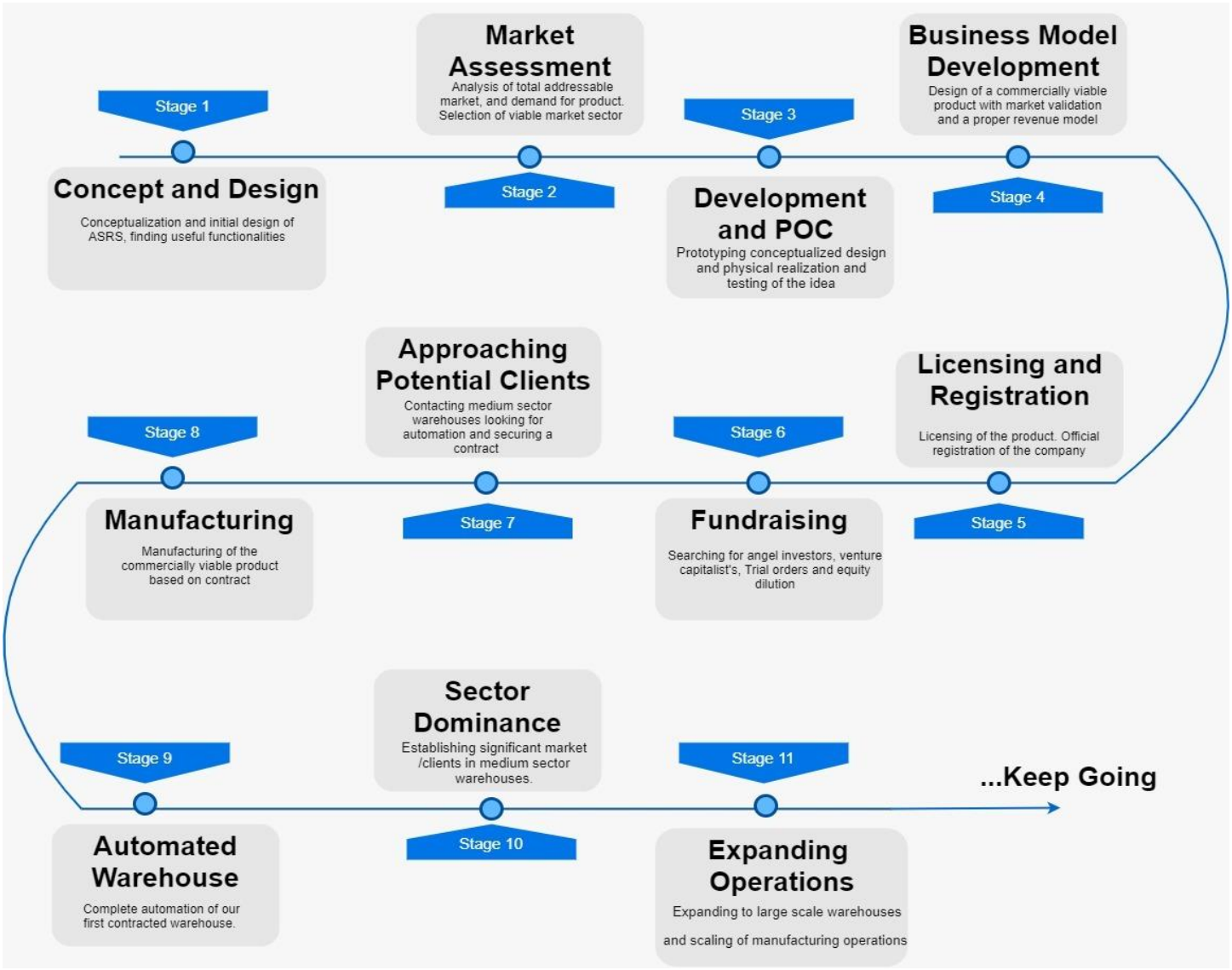
Commercialization Roadmap



Risk factors and mitigation strategies

The risks of developing this system are as follows:

- The system is a radical change intended to be introduced at the lowest level of industry in India. It may not be readily accepted by warehouse owners.
- The production of this system at a mass scale has not been tested yet, and cannot be commented upon.
- The project is a technically complex solution to a prevalent problem in industries. This limits the scope of repairs and after-market services to only the producers of this system.
- In many cases, the positive effects of introduction of SmASRS into warehouses may not become evident immediately.

The mitigation of these issues can be carried out through the following steps:

- By showing true and accurate numbers that chart out the exact advantages of employing the system.
- By rapidly developing scale mechanical models and stress testing materials to fast-track manufacturing approval.
- By making the technology behind the system available through licenses to open up another stream of revenue in after-market repairs and services.
- By introducing SmASRS modules gradually into warehouses to allow owners to study the profits from a small investment and decide accordingly.

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