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COMMODITY DISTRIBUTION MANAGEMENT SYSTEM BASED ON SPRING BOOT

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ABSTRACT

In today's world, a number of humanitarian efforts are being conducted and will continue to happen. This is due to various issues such as victims of certain disaster, refugees, marginalized groups, etc. A lot of independent organizations are making efforts in providing legal, financial, psychological, and health-related support. The planning and distribution of certain food and non-food items isn't a straight forward job. It comes with challenges such as dealing with emergency situations, registration of beneficiaries, dealing with uncertain population estimates, establishing optimal number of distribution points and the requirement for smart need assessment. In this paper we have presented a design of a commodity distribution management system that is based on spring boot technology. The system effectively collects, stores, analyzes information and enables making timely decisions. The system reduces the delays in information processing and decision making and helps dealing with challenges like smart need assessment, establishing the optimal number of distribution points, aggregating and cross-verifying distribution data with the feedback from beneficiaries.

INTRODUCTION

Commodity distribution is the supply of commodities (both food and non-food items) to those who need it, fairly, free of charge, as humanitarian assistance. The beneficiaries of the distribution can be those who are under-privilege, vulnerable, victims of some disaster, refugees etc. The handover of commodities takes place according to specified rations, selection criteria and priorities. The commodity distribution process involves steps such as procurement, transportation, and storage, handling and final handover. The distribution can be the relief commodity distribution, which is distributed to victims of certain disaster like flood, earthquake, famine etc, or the project food aid, which is distributed to groups at risk to improve their health and nutrition. For an effective commodity distribution, it is usually a combined effort of parties such as host government, the distributor NGO, and sometimes

third parties. A smart distribution system based on the information combined and verified from multiple sources is a crucial factor in success of a distribution system. Besides, there a number of challenges that needs to be faced in implementing an effective commodity distribution system. These challenges are dealing emergency situations, registration process, ensuring transparency, dealing with uncertain population estimates, smart need assessment, establishing optimal number of distribution points and information dissemination to all beneficiaries. An effective commodity distribution system should handle these challenges and design and implement strategies that turn these challenges into opportunities. The role of a management information system in designing an effective humanitarian system isn't hard to understand. Management information systems that provide timely access to complete, appropriate, and dependable information are crucial to humanitarian activities. If the humanitarian community is able to gather, examine, disseminate and act on important information timely, the response will be more effective, the needs will be met in a better way, and the affected populations will have a greater advantage (Van de Walle, Van Den Eede, & Muhren, 2008). In this paper, we present a smart commodity distribution management system that is based on spring boot technology.

The system encompasses all important activities of distribution process, helps in collecting, storing, analyzing and smart and timely decision making. The Spring Boot is a framework intended to simplify the development process of new Spring applications. The framework exploits specific ways for configuration which makes it possible for developers to avoid lengthy and overlapping configurations. Hence, the framework is gradually becoming a leader in the area of rapid application development (Chen & Pan, 2020). The rest of the paper is organized as follows: Section 2 discussed the earlier work in the field of humanitarian aid, Section 3 discusses the commodity distribution process with a brief overview of the challenges faced during commodity distribution, and Section 4 presents activities related to monitoring and reporting. Section 5 presents workflow design and architecture of our system, while Section 6 concludes the paper and Section 7 presents future directions.

Related Work

Despite collective food security has enhanced evidently over the past decades, due to increasing global food accessibility per capita and declining food prices, hunger, malnutrition, and food insecurity continue to prevail, roughly one billion people suffering malnutrition today, and at least one-third of the world's population suffers from risk of malnutrition (Barrett, 2002). Refugees from middle-east, Africa, Afghanistan and other countries have been a matter of concern for the host governments, as to how to ensure their health, nutrition, economic opportunities etc. Therefore, a number of organizations, such as United Nations High Commissioner for Refugees, among others have been involved in providing international protection and humanitarian aid in collaboration with other partners, such as World Food Program etc. (Loescher, Betts, & Milner, 2008). Along with these organizations, other NGOs have been actively involved in providing the humanitarian aid to those who need it.

The aid is usually provided in the areas including, but not limited to, financial, social, psychological, health and nutrition. Of these areas, the aid that is provided in the form of food and non-food items is the focus of this paper. These commodities i.e., food and non-food items, are distributed among the beneficiaries, such as marginalized groups, refugees, etc. through a comprehensive planning. The NGOs, continuously work on building capacity, and ensure preparedness for emergency situations as well as routine humanitarian aids. Nevertheless, this isn't an easy task. These organizations have to deal with a lot of challenges such as lack of community (Sampson, McAdam, MacIndoe, & Weffer-Elizondo, 2005) (*Commodity Distribution*, 1997), unreliable or non-current population estimates (Wardrop et al., 2018), marginalized groups and nutritional status (Walker & Fox, 2018), timely and widespread dissemination of information to the beneficiaries (*Commodity Distribution*, 1997). To deal with these challenges there is a dire need of collecting, storing, analyzing information through multiple sources which is timely and helps in smart decision making for an efficient distribution system (Van de Walle et al., 2008).

Commodity Distribution Process

The commodity distribution process begins with initial need assessment, registration of beneficiaries, setting up distribution points, procurement of commodities, their storage and transportation, and finally the hand-over to the beneficiaries. The need assessment involves activities such as identifying the target geographical area, defining the target groups, estimating the population of the beneficiaries, identifying what items are needed and in what quantity. Registration of the beneficiaries is an important step which helps distributing the commodities in an efficient manner. However, in cases of emergency it is not always possible to register the beneficiaries and the distribution must start before the registration. Nevertheless, in such cases, the distribution should contribute to designing an efficient distribution process, for example, the hand-over and registration may continue simultaneously. After the need assessment and registration, the procurement of the commodities takes place, following which the commodities are transported to the already established distribution points. While setting up the distribution points, factors such as the type of geographical area and access of beneficiaries, the number of staff available, the transportation cost must be considered and hence an optimal number of distribution points may be selected. The final step of distribution process is the hand-over of commodities to the beneficiaries. There are several types of distribution strategies with pros and cons of each. The strategies are:

a) Distribution to Individuals:

The hand-over of commodities is made to individuals who are not part of a family neither staying together as household with other individuals. This includes single/divorced/widowed men and women without children or not staying with children, and the children whose parents have died or are unknown, or parents have permanently abandoned the children. This is the lowest level of distribution.

b) Distribution to Head of Family:

The hand-over is made to a representative of a family, and is nominated by the family and generally acceptable to society as head of the family.

c) Distribution to Head of Household

The UNHCR (*Commodity Distribution*, 1997) defines household as "*A group of people living together who pool their resources. They may or may not be members of the same family*". In this paper, however, we define household as the individuals who are living together and are not part of the family. The household may then nominate an individual from among the group and distribution to the household is made through that individual.

d) Distribution to Head of group of families

The commodities are distributed to a nominee of the group, following which the commodities immediately handed-over to the heads of the families by the nominee.

Each distribution strategy has its own advantages and disadvantages. Moreover, the distribution strategy also depends upon factors such as the registration status, the level of emergency and need to speed up the distribution, among others. A comparison of the strategies is given in Table 1.

ACTORS IN COMMODITY DISTRIBUTION

The actors in the commodity distribution are:

Distributor NGO Staff

The main actor in the commodity distribution is the NGO carrying out the humanitarian efforts in a particular region. The distributor NGO staff is responsible for carrying out procedures such as procurement, transportation, need assessment, storage handling of commodities, registration, final hand-over to beneficiaries, and monitoring and reporting. Moreover, the distributor NGO performs identifying the target area, and population estimates, information dissemination in co-ordination with the host government and/or independent third parties for that purpose. The distributor NGO staff includes those responsible for procurement, warehouses, field staff and managers.

Beneficiaries

The beneficiaries are the target of the whole distribution process, and recipients of the humanitarian effort. The beneficiary is an individual who is in need of a humanitarian effort. A beneficiary may or may not be a part of a family and includes marginalized groups, and vulnerable such as women and children. The beneficiaries take part in registration, information recipients, part of the monitoring process accompanying the distributor NGO staff and provide feedback about the distribution process. The beneficiary also sometimes becomes part of the distribution process itself, in cases where the distribution is made through head of families, or nominees of group of beneficiaries.

Government Representatives

The humanitarian effort in any country must be done in co-ordination with the host government to ensure the smoothness of the process. This is also required that any NGO has to follow government rules regarding type of commodities to be distributed, for example items banned by the government cannot be distributed among the beneficiaries. Moreover, the NGO may require certain type of information from the host government; involving the government representatives facilitates the distribution process.

Challenges in Commodity Distribution

Establishing an effective distribution process isn't an easy job. It requires a lot of infrastructure, information, planning and monitoring. Some of the major challenges of distribution process involve the following:

Emergency Situations

Ideally the distribution process should begin when the registration of the beneficiaries is complete. However, in cases of emergency, especially in the early stages, we have to start distribution before registration. In such cases it becomes difficult to track and monitor the distribution process. Therefore, the distribution should be done in such a way that it performs some sort of registration simultaneously during distribution. Moreover, if possible, the distribution should be started only when at least a minimum framework is in place, and there is a plan about improving the next distributions.

Defining Target Groups

Another challenge in the distribution process is how to define target groups. The distributor NGO needs access to data about the areas and/or groups that need the aid. This data can be collected by the NGO itself or by the host government or third parties.

Population Estimates

Population data that is correct have a lot of uses by governments, NGOs, and companies, which include service planning and delivery, preparation of elections, estimation of populations who are at risk for certain contagious disease, and relief management for certain natural or man-made disasters (Tatem, 2014). The key sources of the demographic data are the population census, normally conducted once after every 10 years (Nations, 2015), and national records of births and deaths (Office, 2014). Nevertheless, in cases where there are insufficient resources, the national records are generally incomplete (Ye, Wamukoya, Ezeh, Emina, & Sankoh, 2012) (Linard & Tatem, 2012). The population data reliability in many countries is questionable due to the factors such as correctness of projections required from extended delays between listing and data release (Fig. 1.), the oversight or undercounting of certain minority groups, insecurity limiting listing in some regions, and corruption among others. Therefore, the correct estimates of population are a

major challenge for an effective distribution system and hence there is a need to devise some mechanism to collect and maintain reliable population estimates.

Distribution Strategy	Where to Use	Advantages	Disadvantages
Distribution to Individuals	The individuals are not part of a family. The strategy may be used to hand-over commodities to single men and vulnerable including women and children	The lowest level of distribution where the hand over is made directly to the individuals without any intermediaries involved. Achieves highest level of transparency	Requires a lot of staff and time for completing the distribution process, crowd problems can create security issues
Distribution to Head of Family	Settled population where people are living as families.	Good control over the distribution process to each family. It is easy to target groups at risk. Transparency is high. Better monitoring of female households and vulnerable families.	Requires a lot of administration and infrastructure, cannot be used without registration and family record verification
Distribution to Head of Household	Can be used in camps where people are not part of the same families, but living together.	Helps forming the communities, and distributing to people living together but not part of family.	An unrepresentative head can misuse the authority, therefore requires a lot of monitoring, less transparency
Distribution to Head of group of families	Can be used in camps. When the groups are mostly homogeneous, where the groups are living as families.	Increases interaction among the beneficiaries, the distributor can have some influence over the selection of nominee, women representation can be ensured, specialized groups	A lot of administration is needed to form family groups. Information must reach to all beneficiaries, verified population numbers are needed. An

		can be made, for example which include all women, all minorities, etc. Requires less number of staff, less time, crowd problems are avoided	unrepresentative or abusive head of the group may be a problem. Requires a lot of monitoring to ensure the head distributes the commodities to individual head of families properly.

Table 1: Comparison of Distribution Strategies

Resources Needed to Implement the System

In setting up a distribution system, the resources play a crucial role. The resources such as time, number of staff, financial resources and transportation are some of the major resources we need to implement the system. These resources affect the decisions such as how many distribution points should be established and at what locations, what distribution strategy should be used, distributing after/before the registration. Therefore, the plan must be made keeping in view the available resources. Only then an effective distribution system can be implemented.

Information Dissemination

It can be shown that one of the most important factors in the success of distribution systems is to make sure that the beneficiaries have enough and timely information, failing which the information and misinformation regarding the distribution among the beneficiaries will be circulated, which can get uncontrollable (*Commodity Distribution*, 1997). The information dissemination to the vulnerable such as women is very important. A distribution system must ensure that the information is not dominated and manipulated by some groups. Moreover, a system must ensure that an ordinary beneficiary has easy and shortest access to correct information.

Registration

The registration of the beneficiaries is perhaps the most important step in the whole distribution process. The registration helps planning the distribution, ensuring that commodities reach the beneficiaries in proper way, monitoring the distribution process, making follow-ups and replacement of consumable commodities. Hence, the registration guides the whole distribution process. Nevertheless, the registration isn't always easy and even at some situations it isn't possible to start distribution after registration. For example, in circumstances of emergency it is usually needed to start distributing commodities before registration. The registration process usually requires data such as census from government and/or third parties. The data may be cross-verified from other independent third parties to ensure better distribution.

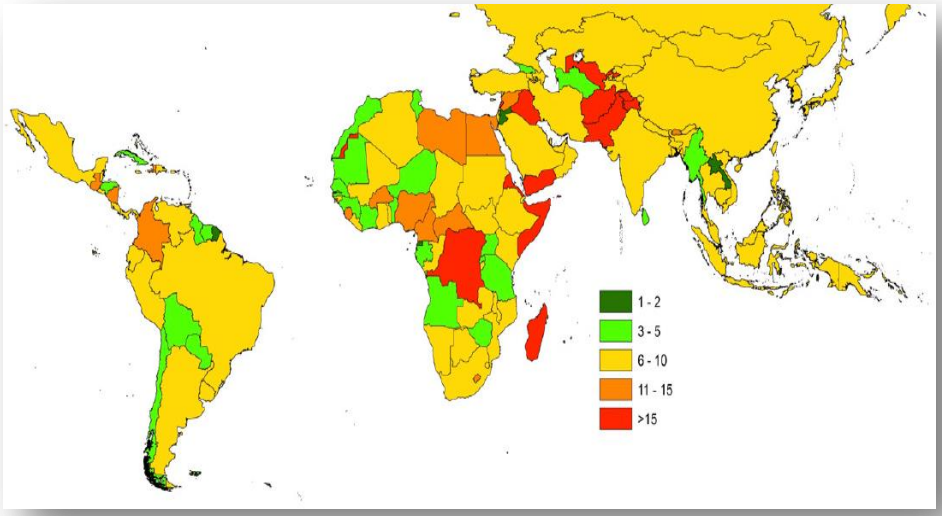

Figure 1. At the beginning of 2017, the number of years since the last national census in countries across Latin America, Africa, and Asia. Picture from (Wardrop et al., 2018)

	Pros	Cons
Few Distribution Points	Requires less number of staff and infrastructure Less transportation cost	Extended distance to the places of beneficiaries Risk of crowd Hard for beneficiaries to monitor the distribution, lack of self-policing Difficult to reach by weaker beneficiaries such as elderly and ill.
Many Distribution Points	Can avoid crowd problems Easier access for weaker and vulnerable Shorter distances to the place of beneficiaries Beneficiaries can monitor the distribution taking place, self-policing is enabled Special arrangements can be made	Requires lot of staff and transportation cost More infrastructure required

Table 2. Pros and Cons of Few or Many Distribution Points

Challenges Related to Need Assessment

The need assessment involves knowing the type and quantity of commodities. Once we have defined the target groups and the registration is completed (where possible) the need assessment is performed so that the commodities should be procured and transported to the distribution points. The need

assessment should be smart; it should include demographics of the beneficiaries such as gender, age, nutrition status, climate conditions among others. These data should be smartly used to define the type and quantity of commodities.

Monitoring and Transparency

An effective distribution system ensures that the commodities are properly delivered to the beneficiaries in a transparent manner. This is made possible using a system which minimizes the misuse of authority at any stage, such as misuse of authority by an unrepresentative nominee of a group of household or group of families. Special care must be taken for the marginalized groups/individuals. The distribution system is monitored at every stage from the registration, procurement, need assessment, final hand-over, replacements and follow-ups. The transparency of information, feedback and involvement of beneficiaries are some of the strategies that can be used for achieving the said purpose.

Storage Handling

Once the commodities are procured, they are stored for a period until the final distribution. The storage period depends upon factors such as procurement dates, type of commodity, number of storage resources available etc. Therefore, a distribution should be planned keeping in view these factors, and the information can be used to set up distribution points and hand-over dates accordingly.

Optimal Number of Distribution Points

In general, the distribution points should locate near to the beneficiaries and placed in such a way as to minimize the crowd attending a single distribution point at a single point of time. It helps them to move the commodities to their place, minimizes the risk of theft, harassment and reduces the time when they are away from home especially in households that are headed by females. UNHCR (*Commodity Distribution*, 1997) defines that, "for dispersed populations, refugees should not have to travel more than a maximum of 10km to distribution points". While setting up distribution points, factors that affect women's reach should be taken into account, such as physical security and distance.

However, setting too many distribution points need a lot of resources. Therefore, an optimal number of distribution points are a practical requirement. There are pros and cons of each of the too many distribution points or too few of them (*Commodity Distribution*, 1997). These are presented in Table 2.

MONITORING AND REPORTING

To ensure the effectiveness of distribution system, monitoring plays a vital role. It is a continuing assessment and control by administration to guarantee that things are proceeding as per plans and budget. The goal of this activity is

to help in the achieving the effective performance through tracking advancement towards the set goals. It provides feedback to administration that helps improving the plans and timely corrective measures when needed. UNHCR has defined various elements of monitoring and the system discussed in this paper takes some of the formats for reports from UNHCR guidelines (*Commodity Distribution*, 1997). The elements of the monitoring include the following:

Logistic Monitoring

This type of monitoring is performed to track the quality, quantity and aptness of the supply, storage, transportation and distribution of commodities. This includes food distribution monitoring reports and non-food distribution monitoring reports.

On-Site Distribution Monitoring

The purpose of on-site monitoring is to find out whether the selected beneficiaries have received the specified quantity of commodities in a particular time.

Post Distribution Monitoring

The purpose of post distribution monitoring is to evaluate the impact of the distributed commodities to the beneficiaries. We use surveys in assessing the availability status commodities, their accessibility and suitability at the household level.

The monitoring process is accompanied at each level by a number of reports. The format of reports may be designed by an NGO as per need; however, the reports must fulfill the purposes described above. Moreover, the format of the reports may be tailored easily, even by end users, through simple drag and drop. This on-demand reporting is made easy through sophisticated reporting tools. Moreover, the use of rapid application development tools, (such as spring boot that we are using to build this system) make it easy to develop new formats as need arise, in a very short period of time.

PROPOSED METHODOLOGY

We present here, a commodity distribution management system that collects, stores, analyzes information collected through multiples sources and use it for smart decision making in implementing an effective distribution system. First, we present the workflow design of the system in section 5.1. Next, we explain how spring boot can be integrated for rapid construction of such system in section 5.2. Also, we present in section 5.3, how the data can be used for smart decision making in a commodity distribution management system.

Workflow Design of The System

The commodity distribution process begins identifying the target groups and selecting a particular region. The selection can be made in collaboration with

the host government. In cases of emergency, the affected areas are the target groups of the distribution. After selecting the region, the first step should be to start disseminating the information to the area, as it will take time to reach the beneficiaries. In parallel, we obtain the population estimates. The population estimates can be obtained from the census data and verified by distributor NGO by itself or from third party data available. Nevertheless, this will always be an estimate, and we should be ready for small deviations. After sufficient time passed since disseminating the information to the selected area, we start registration process. Note that, this is only the case in normal circumstances, not in emergency situations. In emergency situations, the registration process is executed in parallel to the hand-over. However, a limited framework can be established for the purpose of need assessment and then the distribution is started. The need assessment activity involves assessing what commodities are required and how much of each. We will explain in section 5.3, how the need assessment can be made smart based on demographic information of the beneficiaries. Normally the distributor NGO has some basic food and non-food items kept in advance in warehouses, hence procurement can begin at very early stages. However, in case it is found that one or more items are short they can be ordered timely right after the need assessment. The items are then transported to the established distribution points. The distribution points can be established smartly based on certain criteria like density of population and the type of area; we will show in section 5.3, the optimal number of distribution points can be chosen based on geographical information, and population data. Before starting the actual hand-over it is made sure that the distribution date(s) and points are announced to the beneficiaries. The actual hand-over is performed, based on the selected distribution strategy. The inventory records are updated simultaneously. After the final hand-over the follow-ups are made to assess the distribution status, the feedback from the beneficiaries helps identifying the problems, which in turn guide to improve the distribution process. The monitoring and reporting activities are conducted throughout the distribution process. The workflow of the commodity distribution management system is shown in Fig. 2.

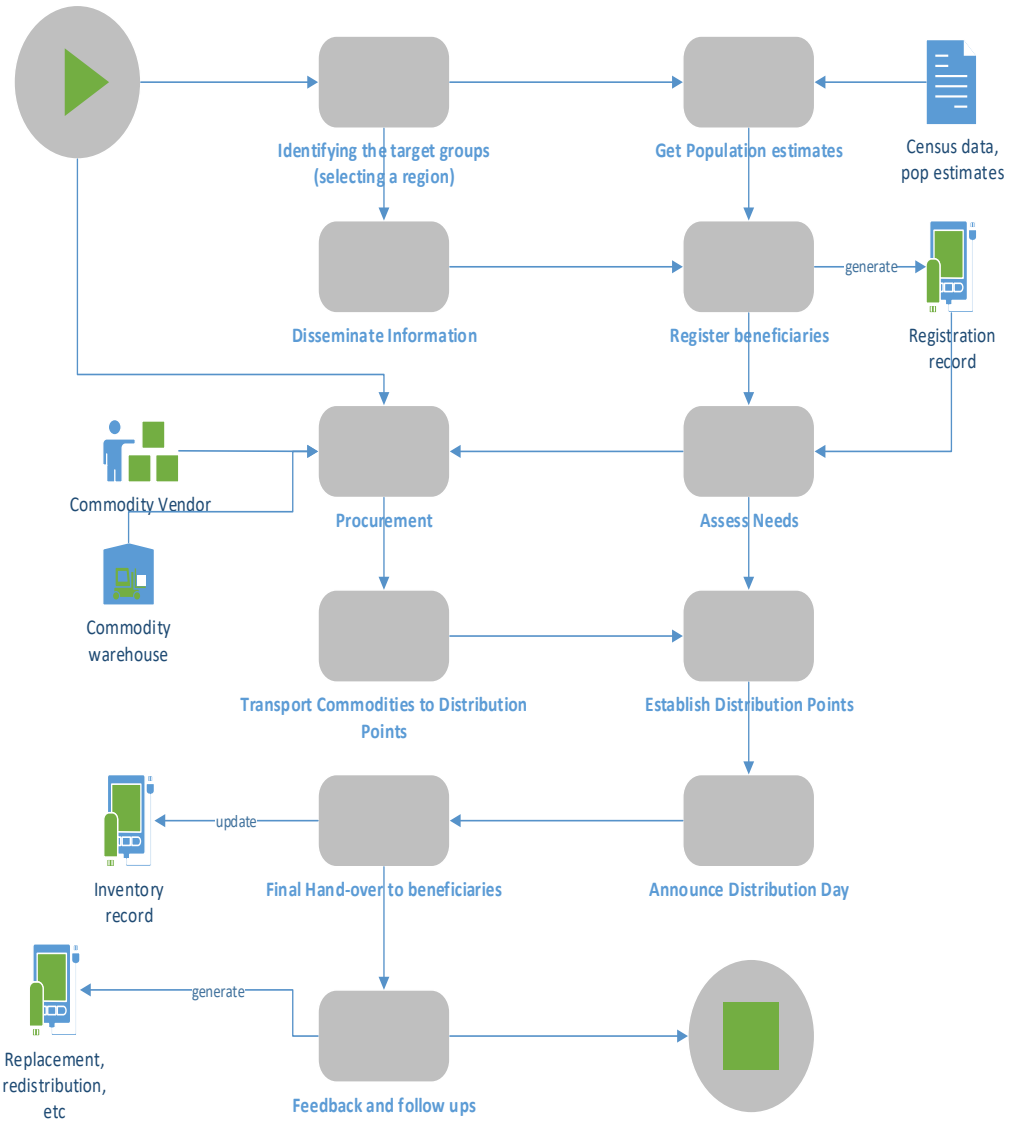

Figure 2: Workflow Design of Commodity Distribution Management System

Spring Boot Integration

We have built our system using Spring Boot framework. Spring Boot framework is built on top of Spring Framework and is used to create, independent ready for production apps with less effort. It follows a layered architecture where each layer communicates with the layer immediately above or below. The four basic layers of spring boot are as follows:

Presentation/Front-End Layer: This layer is responsible for handling the client requests, performs translation of JSON parameter to object, client request is authenticated and transferred to the business layer.

Business Layer: all the business logic is performed at this layer, authorization and business logic validation is performed here, and it comprises of service classes and utilizes the data access layer services.

Persistence Layer: This layer has the storage logic and the translation of business objects into database rows and vice versa.
Database Layer: The database layer consists of the basic operations, like create, retrieve, update and delete.

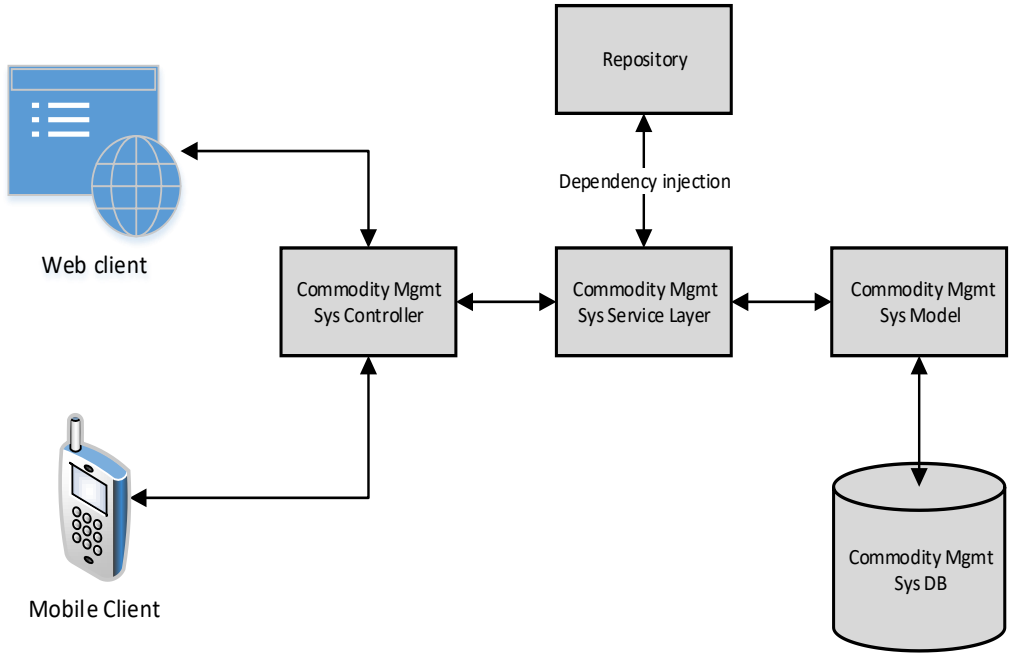

Figure 3: Architecture Diagram of Commodity Distribution Management System

Spring Boot is built on the modules of Spring such as Spring Model View Controller, Spring Data, and others. The architecture of Spring MVC and Spring Boot is almost same except that in Spring Boot we don't need DAO and DAOImpl classes (See Fig. 3.). The client makes the HTTP requests depending upon the type of CRUD operation being performed, like for retrieving the data client will make a GET request, for creating new data or updating the existing data client will make PUT request. The request then transferred to controller, which handles it, and then it calls the service logic, where needed. All the business logic is performed in service layer. The logic is performed on the data mapped to Java Persistence API with model classes. Java Persistence API is part of J2EE and defines an API for managing persistent objects and object-relational mappings. Finally, a Java Server Page is returned to the user as a response.

Advantages of Using Proposed Methodology

Our commodity management system has a number of advantages that make it a desirable system for effective commodity distribution. First, it is based on spring boot technology which helps in development of the system rapidly without developers putting too much effort in configurations. Next, our system combines information from multiple sources and exploits it for smart decision making. Some of the notable features of our system are discussed below:

- Our system will have web as well as the mobile interfaces that enable timely flow of information from the field staff to the warehouses and other departments of the organization, such as procurement and finance.
- The inventory data is kept updated which makes it possible to generate alerts for procurement.
- The non-food non-consumable items like mattresses, blankets, kitchen sets need to be replaced at times. By setting an average life for each of these items, the system may automatically generate alerts, which can be used by procurement department for timely ordering of the items.
- The need assessment activity can exploit demographic information of beneficiaries, such as number of family members, their age and gender, etc., and hence a smart setting of quantity and type of each commodity can be generated from within the system.
- The distribution points should be selected in an optimal way keeping in view the number of staff and accessibility of beneficiaries. Using the GIS based information and these factors, an optimal number of distribution points may be selected.
- The monitoring and reporting throughout the distribution process help in cross verification of distribution status and hence finding and correcting the problem areas.

CONCLUSION

In this paper we have presented a commodity distribution management system that is based on spring boot technology. The system effectively collects, stores, analyzes information and helps in making timely decisions. The system reduces the delays in information processing and decision making and helps dealing with challenges like smart need assessment, establishing the optimal number of distribution points, aggregating and cross-verifying distribution data with the feedback from beneficiaries. This makes it possible for a smooth and effective commodity distribution and optimal use of resources in achieving this. Moreover, our system is built using spring boot framework which enables developers to quickly develop applications without focusing much on configuration. Hence, our system can be used as an effective tool for implementing a smart commodity distribution management system.

Future Work

Our system can be extended to include other parties such as other NGOs working in the same areas. The system can also be extended to include various other distribution strategies. The system can also be extended to provide beneficiary representatives with an interface so that they can directly communicate with the system, where possible. This will help in reducing the feedback time and effort put by the NGO staff.

REFERENCES

Barrett, C. B. (2002). Food security and food assistance programs. Handbook of agricultural economics, 2, 2103-2190.

Chen, J., & Pan, H. (2020). Design of Man Hour Management Information System on SpringBoot Framework. Paper presented at the Journal of Physics: Conference Series.

Commodity Distribution. (1997). Retrieved from https://www.unhcr.org/3c4d44554.pdf

Linard, C., & Tatem, A. J. (2012). Large-scale spatial population databases in infectious disease research. International journal of health geographics, 11(1), 1-13.

Loescher, G., Betts, A., & Milner, J. (2008). The United Nations High Commissioner for Refugees (UNHCR): The politics and practice of refugee protection into the 21st century.

Nations, U. (2015). Principles and Recommendations for Population and Housing Censuses: Revision 3. New York New York United Nations; Department of International Economic and Social Affairs, Statistical Office: New York, NY, USA.

Office, U. N. S. (2014). Principles and recommendations for a vital statistics system: United Nations Publications.

Sampson, R. J., McAdam, D., MacIndoe, H., & Weffer-Elizondo, S. (2005). Civil society reconsidered: The durable nature and community structure of collective civic action. American journal of sociology, 111(3), 673-714.

Tatem, A. J. (2014). Mapping the denominator: spatial demography in the measurement of progress. International health, 6(3), 153-155.

Van de Walle, B., Van Den Eede, G., & Muhren, W. (2008). Humanitarian information management and systems. Paper presented at the International Workshop on Mobile Information Technology for Emergency Response.

Walker, A. K., & Fox, E. L. (2018). Why marginalization, not vulnerability, can best identify people in need of special medical and nutrition care. AMA journal of ethics, 20(10), E941.

Wardrop, N., Jochem, W., Bird, T., Chamberlain, H., Clarke, D., Kerr, D., . . . Tatem, A. (2018). Spatially disaggregated population estimates in the absence of national population and housing census data. Proceedings of the National Academy of Sciences, 115(14), 3529-3537.

Ye, Y., Wamukoya, M., Ezeh, A., Emina, J. B., & Sankoh, O. (2012). Health and demographic surveillance systems: a step towards full civil registration and vital statistics system in sub-Sahara Africa? BMC public health, 12(1), 1-11.