Integrated Production System

by Marti Sari

INTEGRATED PRODUCTION SYSTEM ON SOCIAL MANUFACTURING: A SIMULATION STUDY

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ABSTRACT

Today, the manufacturing industry must adapt to dynamic customer needs, changing from time to time following market trends. So that the production process in manufacturing requires adjustments, one of which is by forming social manufacturing. This study aims to create an integrated production system model based on social manufacturing, which involves several Socialized Manufacturing Resources (SMR) as manufacturing resources that are socialized to produce a product. The methods used are field observation, literature study, design of a social manufacturing-based production system model, model simulation using ProModel software, and analysis of model simulation results. In this study, the simulation involves four SMRs, each of which makes a part that has been given specifications by the manufacturer based on customer requests. The product produced is the Sanitation Chamber, which is equipped with a control system to monitor reading data via the internet. The model simulation uses the Pro Model software and analyzes resource use, location utilization, and resource costs.

Keywords*: social manufacturing, integrated production systems, simulation study, ProModel*

INTRODUCTION

Manufacturing systems, information and management technology, and manufacturing's social environment have developed rapidly in recent years. It has changed a lot, such as increasing global market competition, diversity of customer demands, and so on [1]. Currently, the manufacturing industry is required to meet customer needs that are very diverse and can change at any time and follow specific trends [2]. The Industrial Age 4.0 allows the production system to increase flexibility in making a product customized according to customer needs [3], commonly referred to as product personalization [4]. Mass personalization of products with diverse customer needs and dynamic online market trends have encouraged manufacturers to have various manufacturing capabilities, especially those that appear for personalization or innovative products [3]. But sustainable investment to meet these needs is too large and not profitable for producers' strategic development [2]. Many companies implement an outsourcing/crowdsourcing system to reduce operating costs to react quickly to dynamic markets [5], [6]. With the rapid development of the internet and information technology today [7], interaction, and information between service providers and communities have become easier [8]. On the other hand, time-varying customer demands and production disruptions force manufacturers to increase flexibility in the production process [2].

Social manufacturing involves stakeholders, customers who access products/services via the internet, social manufacturing resources (SMR), and applications used through social media or applications on mobile devices [6], [9]. As a new form of manufacturing, social manufacturing shows the complexity between social-cyber, as the source of manufacturing services is social. Doing so can exacerbate uncertainty and dynamic supply services [10]. The merger of the Cyber-Physical System (CPS) with social media produces a social manufacturing and basic theory for production organizations in the future [11], [12]. At the core of social manufacturing, three aspects are configuration, operation, and management perspectives, which are expected to transform production modes and social innovation [6]. Social manufacturing is proposed as an innovative manufacturing solution for product personalization customization [1], [13]. Besides, social manufacturing is considered to realize "from mind to product" to meet customer demand. The future challenge is to add applications and the prospect of personalized products and services for customers [14]. The social manufacturing community is formed to meet every customer need by grouping small industries according to resources. Every request from customers can be resolved together [15]. Product costs and delivery time are indicators for allocating product orders in the social manufacturing community that has been formed [16].

Facing the challenge of mass demand for product personalization, the manufacturing model has developed into social manufacturing [15], where stakeholders who have manufacturing resources share, for example, small medium-size enterprises (SMEs), logistics service providers, and factory warehouse providers [17], forming a community, referred to as SMR [18], [19], based on social media collaborating with manufacturers to produce a product [20].

Many SMEs and individuals have sprung up with socialized resources and participated in different segments [21]. The small and medium industrial community provides various service-oriented capabilities to meet customer demands [22]. The trend of small and medium industrial communities forming new communities to produce a product has changed the paradigm of manual and automatic manufacturing systems and production modes [12]. This study aims to design an integrated production system model based on social manufacturing, then simulate the existing model using Pro Model software. This integrated production system model involves several SMEs, which form a social manufacturing system and produce a medical device, namely the Sanitation Chamber, to prevent the transmission of Covid-19.

LITERATURE REVIEW

Social Manufacturing Concept

Social Manufacturing is a special production process based on outsourcing and crowdsourcing [5], manufacturing services based on mass socialization in independent organizations, and service orientation towards the mass individualization paradigm [21],[23]. Social Manufacturing mode integrates mass personalization on manufacturing, information interconnection, and product services [15]. Many advanced manufacturing modes have been proposed in recent years, and the multitude of providers, being one of the most visible changes. Development on Flexible Manufacturing [24], [25], Cloud Manufacturing [1], Manufacturing Grid [26], Collaborative Manufacturing [27], [28], Networked Manufacturing [29], and Virtual Enterprise [30]–[32], which emphasize collaboration and interconnection between manufacturers. The manufacturing community consists of many prosumers who share the same interests and tasks in a social manufacturing system. Different users can outsource or add specific tasks from the relevant manufacturing community according to their needs or abilities and then form a virtual manufacturing environment or solutions to complete the manufacturing tasks that result in a product [21].

All manufacturing communities involved in the entire life cycle will support social computing, service-oriented technology, and advanced computing technology [33]. Multiple manufacturing resources and capabilities are virtualized and collected to proactively push into demand knowledge-based using social computing and service-oriented technology. However, there are differences in the manufacturing process, including resource type, resource integration, resource sharing, sharing production coordination, resource management, product life cycle information sharing, information technology used, and their characteristics, as shown in Table 1.

Table 1. The comparison of manufacturing paradigms

Items	**Flexible Manufacturing** [24], [25]	**Virtual Enterprise** [30]–[32]	**Manufacturing Grid** [26]	**Cloud Manufacturing** [1][34]	**Collaborative Manufacturing** [27], [28]	**Networked Manufacturing** [29]	**Social Manufacturing** [15], [16], [21]
Type of resources	Manufacturing resources	Enterprises	Enterprises	Manufacturing resources	Enterprises	Enterprises	Socialized manufacturing resources (SMRs)
Integration of resources	Information and process	Manufacturing resources, data/information, etc.	Manufacturing resources, computing resources, etc.	Manufacturing resources and abilities	Manufacturing resources and abilities	Manufacturing resources and abilities	Resources form product life cycle
Sharing of resource and coordination of production	Within an enterprise	Among several enterprises	Among mass enterprises	Among several enterprises	Based on grid	Among several enterprises	Among the whole society
Management of resources	Centralized	Centralized	Centralized	Centralized	Semi-decentralized	Centralized	Semi-decentralized, self-organized
The Life cycle of product and information sharing	Inter-enterprise sharing	Partially sharing	Partially sharing	Partially sharing	Based on grid	Information sharing	Full-scale sharing
Information technology-enabled	Computer-aided technology	ICT, concurrent engineering	Grid computing, agent, web service	Cloud computing, IoT, RFID, sensor network, etc.	WAN environment	Internet	The Social network, cloud computing, big data, industry 4.0, etc.

Items	Flexible Manufacturing [24], [25]	Virtual Enterprise [30]–[32]	Manufacturing Grid [26]	Cloud Manufacturing [1][34]	Collaborative Manufacturing [27], [28]	Networked Manufacturing [29]	Social Manufacturing [15], [16], [21]
Manufacturing Characteristics	Flexibility, based on modularity	Agility, resource sharing, efficiency	Flexibility, agility, resource sharing, cost-saving	Flexibility, agility, resource sharing, on-demand, value-added service	Flexibility, resource sharing	Flexibility, information sharing	Flexibility, agility, value-added service, social innovation

Socialized Manufacturing Resource

Socialized Manufacturing Research (SMR) is a resource owned by stakeholders in social manufacturing systems, such as small-medium enterprises (SMEs), smart factories, logistics service providers, and public warehouse providers, forming a social media-based community with producers to collaborate to produce products [2]. With the development of the mobile internet and social networks, interaction and sharing of information among service providers have become more accessible. Social manufacturing is interrelated by a contractual relationship between the manufacturer and its partners, while the production sequence relationships are built among SMR providers [16], [35]. Many SMRs with decentralized, adaptive, and self-organizing characteristics began to group as communities to provide specialized manufacturing services to prosumers [36]. SMR communities are complex, dynamic autonomous systems to co-create individualized products and services [6].

RESEARCH METHODS

The method used in this study is conducting field observations, literature studies, designing a social manufacturing system model, testing the system, and analyzing the test results. This research takes a case study on an integrated production process based on social manufacturing to produce a medical device in a Sanitation Chamber. During this pandemic, the need for medical devices in a sanitation chamber is urgently needed to prevent Covid-19 transmission. As demand increases, production can be carried out quickly and distributed to various public service facilities. Based on this background, this research will develop a social manufacturing-based sanitation chamber production system involving SMRs. Field observations and literature studies have been carried out and involved several SMRs. The following process compiles a social manufacturing system model and then simulates the model using ProModel software.

System Design

The design of the social manufacturing system in this study is presented in Fig. 1, which involves four SMRs to make a product. Each SMR makes the components that make up the product, according to the specifications provided by the Manufacturer. After each component is ready, it is then sent to the integrator for the installation and assembly process.

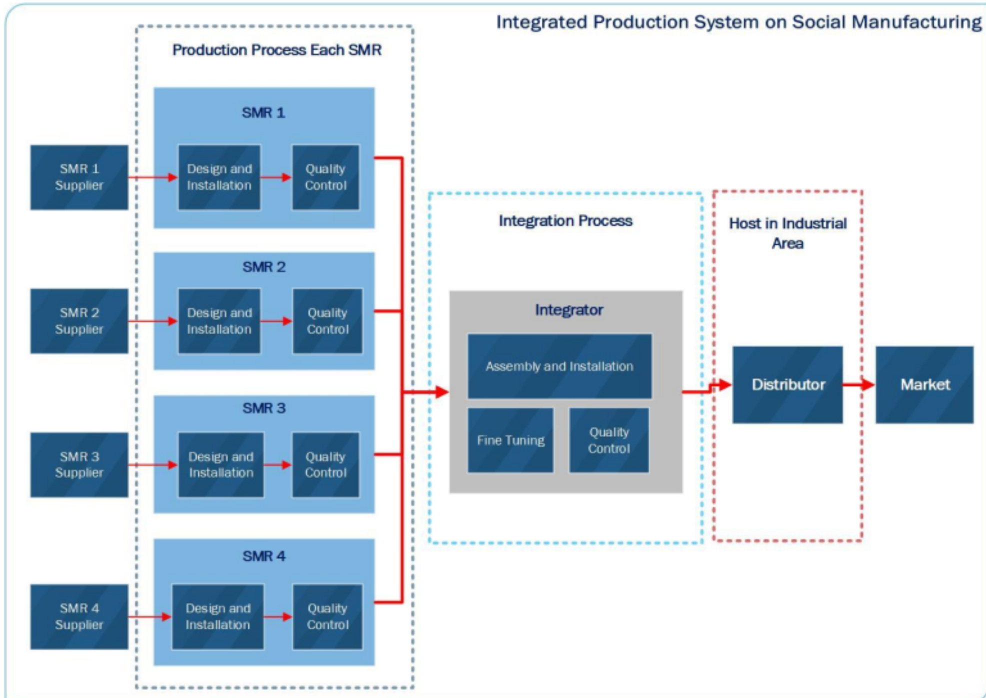

Fig. 1. Social Manufacturing system design

System Model Simulation

The social manufacturing system model simulation was carried out using the ProModel software, with the steps as presented in Fig. 2. The first step is to create a model of the social manufacturing system in the ProModel software. Then, input data for the social manufacturing system, such as the number of SMRs involved, the assumption of working hours per day, the cost required to make a part for each SMR and the placement of the SMR locations, because it will determine the transportation costs. Furthermore, the simulation can be done through the Run button on the ProModel, and then the results can immediately be seen on the monitor in the form of tables and graphs.

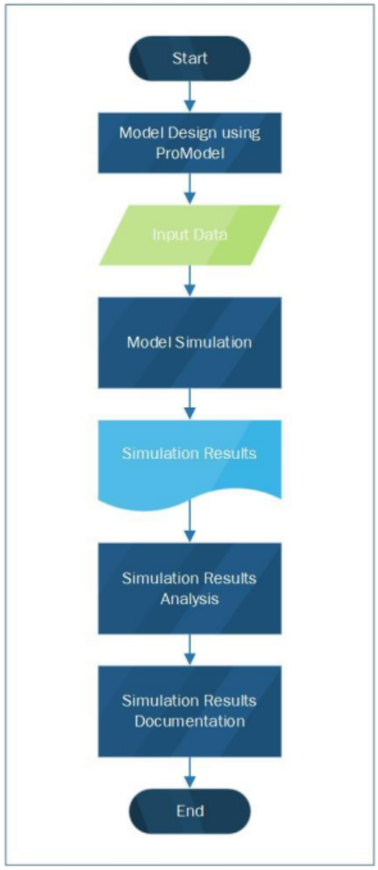

Fig. 2. System model simulation flowchart

RESULTS AND DISCUSSION

The difference between the social manufacturing system in this study and Ding's research is the social manufacturing system model. In research conducted by [2], a social manufacturing system was created by involving several SMRs with far apart locations, to produce printer machines. Each SMR completes a part then is continued and combined by the next SMR until the product is finished and returned to the manufacturer. In this study, the simulation involves four SMRs, each of which makes a part that has been given specifications by the manufacturer based on customer requests. The product produced is the Sanitation Chamber, which is equipped with a control system to monitor reading data via the internet.

In this simulation study, four SMRs produced a Sanitation Chamber, namely PT ATMI, CV Bisri, CV Alfan, and CV Ekrar. PT ATMI is tasked with making body frames made from stainless steel, and CV Bisri is in charge of designing and installing the sprayer, CV Alfan is in order of designing and installing the controller. CV Ekrar is in charge of developing an internet of things (IoT) based monitoring system application. The system model that has been made is presented in Fig. 3. Each

SMR designs product components at their respective locations, then after the components are finished, they are assembled and integrated with other parts at the PSE. We got all information about the production process, such as material supplier, production time, and production costing, through field observations and in-depth interviews with the owners.

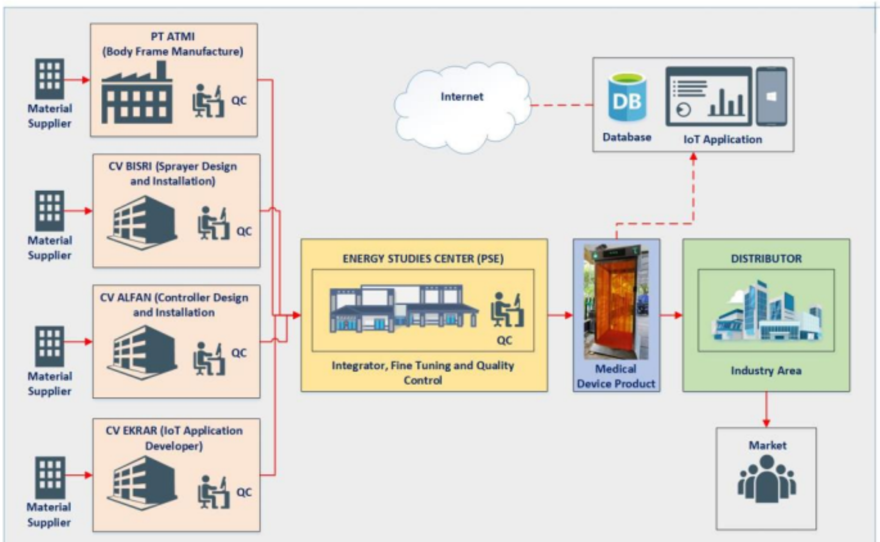

Fig. 3. Social Manufacturing System Model

The process of designing and installing components in each SME can be done in parallel, so there is no waiting for one of the components to be completed. The initial process starts with the Center for Energy Studies (PSE). We design an integrated production system to produce a Sanitation Chamber, starting from selecting SMEs, device design, what raw materials are needed, and what costs are required, including the estimated total time needed to make this product. Then, we sent the device image's design to the SMEs involved being executed immediately. PT ATMI makes the body frame for the Sanitation Chamber using stainless steel base material to ensure that this device can last longer and be easier to clean. In making this body frame, PT ATMI took about two weeks. For information, that PT ATMI has good competence in terms of making frames. PT ATMI's business location is in Solo, Central Java, about 64 Km from Yogyakarta. Therefore, communication and coordination are carried out via WhatsApp and mobile phones.

Furthermore, CV Bisri designed the sprayer installation on the body frame by the specifications of the drawings. The production process of this sprayer takes about a week. Then, the sprayer components were brought to PSE for the integration process with the body frame. CV Alfan carried out the control system's design and installation according to the specifications we have provided. The control system that has been completed is then brought to PSE to be assembled and integrated with other parts. All hardware requirements were met, then the device was built and integrated with other components. Quality control is also carried out to test the feasibility of the devices that have been made. To monitor the results of temperature measurements at the Sanitation Chamber, an Android-based application was created by CV Ekrar so that the results can be watched anywhere. The simulation results using Pro Model software (Fig. 4) are presented in Table 2.

Table 2 The results of Location States Multi from Pro Model software

Name	Scheduled Time (HR)	% Empty	% Part Occupied	% Full	% Down
Controller Supplier (1)	165.03	65.4441	34.56	0	0
Sprayer Supplier (2)	114.69	95.30382	4.7	0	0
IoT Application Supplier (3)	114.69	95.30382	4.7	0	0
Raw Material Supplier (4)	354	17.28993	82.71	0	0
Design Installation 1	234	41.10704	52.49	6.399003	0
Design Installation 2	180	60.26455	3.72	36.01706	0
Design Installation 3	318	24.67805	24.6	50.72544	0
Design Installation 4	528	9.956708	90.04	0	0
Quality Control 1	304	22.76002	77.24	0	0
Quality Control 2	306	21.25817	70.9	7.843137	0
Quality Control 3	456	10.63074	84.1	5.274123	0
Quality Control 4	314.1	23.62305	76.38	0	0
Assembly Installation	146	74.10959	25.89	0	0
Fine Tunning	114	94.73684	5.26	0	0
Final Quality Control	222	35.13514	64.86	0	0
Distributor	318	25.25157	74.75	0	0
Market	127.5	100	0	0	0
Reject Warehouse	114	100	0	0	0
Joint 1 2	510	5.676471	94.32	0	0
Joint 3 4	114	94.47368	5.53	0	0

Table 2 presents data on the scheduled time for each production process in hours (HR). The average time it takes to complete the product is 252.70 hours. The body frame's design and installation process have the highest load time, which takes 528 hours. The lowest load time is in the fine-tuning and rejecting warehouse processes, which is 114 hours. Percent Empty means the percentage of the production system actively. The smaller the percentage value, meaning that the system does a lot of work in a specific time, and vice versa if the percentage value is higher, it indicates that the system is idle. Percent Occupied shows the level of use of each part in an integrated production system. In Table 2, it is shown that the highest percentage level of use is 90.04% in the body frame manufacturing process, and the lowest level of use is 3.72% in the sprayer installation process. There are four entities in this integrated production process, namely controller, sprayer, IoT application, and body frame. The simulation results for each entity's activities are presented in Fig. 3, which shows the system's current quality, the average time in the system, the average time in move logic, average time waiting, the average time in operation, and average time blocked. The average time in the system is 28965 minutes. The average time in move logic is 11054.03 minutes. The average time waiting is 6 minutes. The average time in operation is 14580 minutes, and the average time block is 3324.97, in the final product BICO-19.

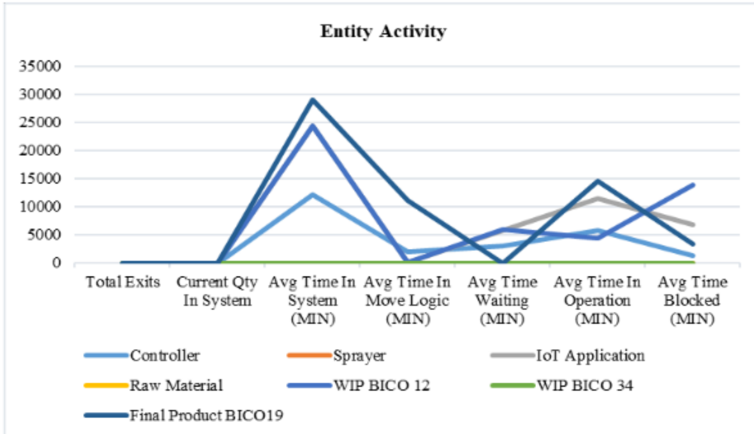

Fig. 4. Simulation results for Entity Activity

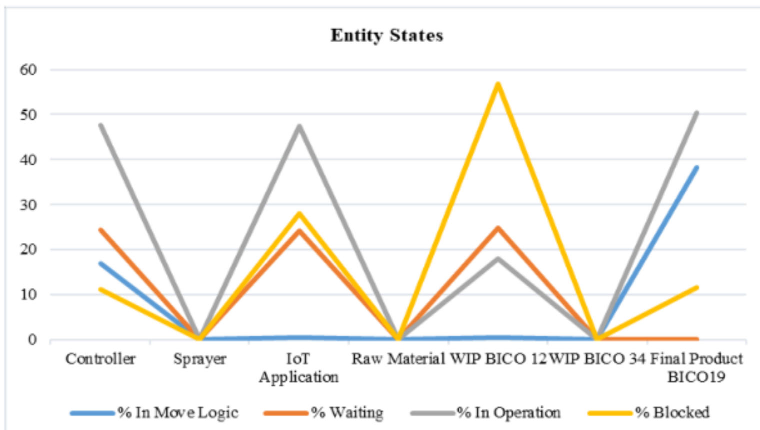

Fig. 5. Simulation results for Entity States

Fig. 5 displays entity states for the controller, sprayer, IoT application, and raw material of body frame, showing the percentages in move logic, waiting, operation, and block. The average value of the move logic percentage is 7.98%, the waiting percentage is 10.47%, the operation percentage is 23.34%, and the blocked percentage is 15.36%. Furthermore, location utilization in an integrated production system is presented in Fig. 6. The highest location utilization is 59.78% for design and installation 3 (IoT application), while the lowest is 0.88% for fine-tuning.

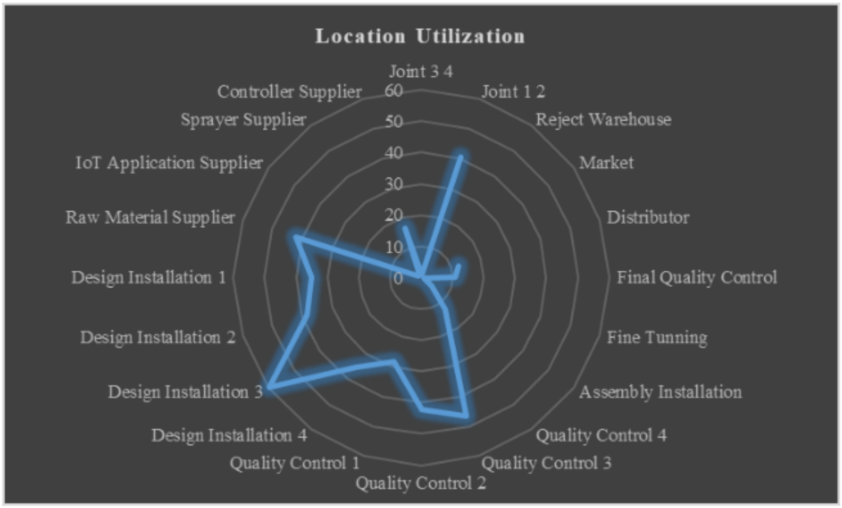

Fig. 6. Location Utilization

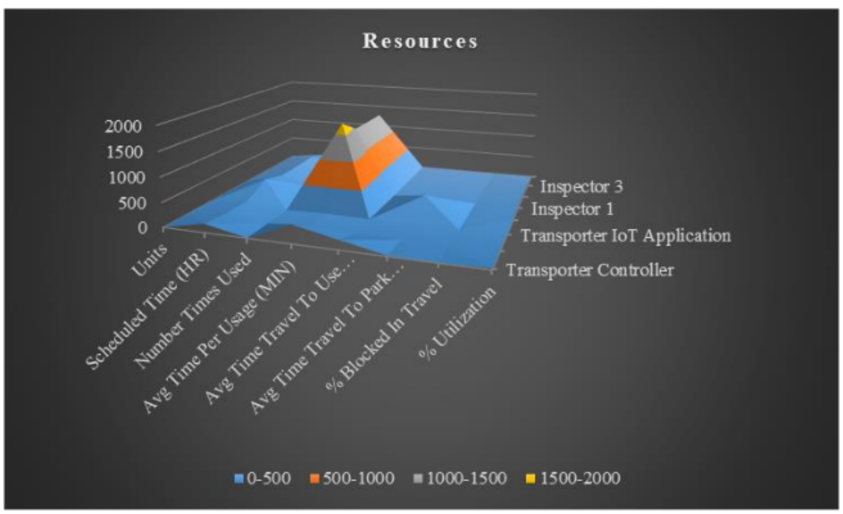

Fig. 7. Resources simulation results

The use of resources for transporters and inspectors consists of the number of units, scheduled time (hour), number of times used, average time per usage (minutes), average time travel to use (minutes), as shown in Fig. 7. The average value of scheduled time for transporters was 189.79 hours, and the average value for inspectors was 202.46 hours. The highest value of Average time per usage is 1714.29 minutes in raw material of body frame production, and the average time per usage value of all transporters is 535.71 minutes. The average time per usage for inspectors is 1080 minutes. The average time travel to use transporters is 53.75 minutes, while for the inspectors, it is 0 minutes because they did not move anywhere. The average travel time to park for transporters is

91.59 minutes, while for inspectors, it is 0 minutes because they do not travel; they only work at the production site.

Furthermore, the percentage of utilization in transporters is 21.79%, and for inspectors is 46.69%. The rate of blocked travel is 0% because overall, the production process is running as planned. The transporter value for the scheduled time on the body frame's raw material is the highest, 353.17 hours because the distance from the production location is far from the PSE assembly site. Then, the estimated resource costs for transporters and inspectors are presented in Table 3. Determination of the cost of each resource in each SME based on the estimated real needs to produce a sanitation chamber product. The highest percentage of usage cost was 37.43% for the transporter for raw material of body frame, with a total price of around 180 USD, and the portion of the total cost was 31.29%.

Table 3 Resource costing

Name	Units	NonUse Cost Dollars	% NonUse Cost	Usage Cost Dollars	% Usage Cost	Total Cost Dollars	% Total Cost
Transporter Controller	1	0	0	107.1	22.2763	107.1	18.6185
Transporter Sprayer	1	0	0	42.84	8.91052	42.84	7.447402
Transporter IoT Application	1	0	0	42.84	8.91052	42.84	7.447402
Transporter Raw Material	1	0	0	180	37.43916	180	31.2916
Inspector 1	1	19.0601	20.17922	36	7.487832	55.0601	9.571774
Inspector 2	1	20.7625	21.98156	36	7.487832	56.7625	9.867721
Inspector 3	1	26.1315	27.66585	36	7.487832	62.1315	10.80109
Inspector 4	1	28.5	30.17337	0	0	28.5	4.954504

Most of the production needs were in the body frame's manufacture because the primary materials used are excellent, made of stainless steel, so the price is high. Meanwhile, for the inspector's cost, the highest value is the inspector 3, 62.13 USD with a total cost percentage is 10.80%, namely in making IoT applications, which require a lot of services rather than raw materials. This IoT application is connected to a modem in the control system connected to the internet to access temperature measurement data anywhere.

CONCLUSION

Simulation of an integrated production system model is essential because it can measure the actual system to be built. In this research, a framework design and integrated production system model in social manufacturing have involved four SMEs in producing a medical device in a sanitation chamber. Based on the literature [2], [6], [35], in this social manufacturing-based production system, reaching an agreement between the manager and the SMEs involved is carried out by direct discussion and communication so that all tasks are carried out based on the trust of each stakeholder. The total time needed to produce a sanitation chamber is around 30 days, with eight working hours per day, so the working hour is not counted as complete 24 hours. In this research, only model design and simulation were carried out. Some things can still be improved for further study with different methods, such as making optimization using mathematical models, discussing production cost problems, and the effectiveness of SMEs' involvement in social manufacturing systems. Researchers can also compare conventional production systems (non-social manufacturing) in factories with an integrated production system based on social manufacturing.

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