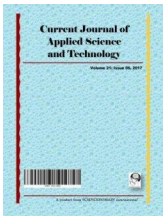

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Remanufacturing as a Service Embedded within Closed Loop Cloud Manufacturing System-Literature Review Based Design

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Authors' contributions

This work was carried out in collaboration between all authors. Author ZTA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors GSS and SBY managed the analyses of the study. Author ZTA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Conclude enablers to embed the remanufacturing as a service within the infrastructure of cloud manufacturing system to service closed loop supply chain of sustainable manufacturing through integration of educational institutions.
Study Design: Recent cloud manufacturing architectures are combined to be modeled again to take into consideration remanufacturing as a service to be conducted by educational institutions.
Methodology: Comparative literature is used to find out some statistics to show directives of literature to help embed remanufacturing within the architecture of cloud manufacturing. Thus statement of enablers can be proposed and architecture of cloud manufacturing of remanufacturing as a service can be emerged.
Results: Sustainable approach is more suitable to be applied within societies that suffer from non-

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clear human development, lower education standards, without industrial infrastructure and weak communication technologies where increasing awareness of environment protection required business for value creation to be conducted. Remanufacturing will enable such societies to be linked with industrial institutions economy by establishing remanufacturing business model which is embedded as a service within the cloud manufacturing. This approach will encourage such societies to apply strict regulations to protect customer and increase value-added of imported products which end the cheap product paradigm and help new markets to be included. Resources of universities are integrated to process the remanufactured products and value creation will be certain sustainability based on human development, employment and ecosystem establishment. **Conclusion:** Two main directives of literature can be classified to include macro-literature and micro-literature according to degree of consistency with the aim of closing the loop of cloud manufacturing by remanufacturing as-a-service to be delivered through the same platform of cloud manufacturing. Macro-literature focuses on the economics of remanufacturing with no sign for closed loop cloud manufacturing with remanufacturing through inclusion of educational institutions to apply sustainable development. Micro- literature is consisted for some extend with aim of sustainable cloud manufacturing but it is with technological dimensions. So much more consistent directives of literature are proposed to be taken in consideration by researchers to cover the area of close the loop of cloud manufacturing with educational institutions through application of remanufacturing. Thus an absolute measurement of sustainability with more clear social criteria can be introduced. Review of literature enables classification of macro-literature, micro-literature and barriers of remanufacturing which can be used to analog control system for assessment of literature maturity in two directions of embedding remanufacturing and educational institutions within structure of cloud manufacturing.

Keywords: Closed loop cloud manufacturing system; educational institutions based; remanufacturing; remanufacturing as a service.

1. INTRODUCTION

1.1 Literature Assessment

Independent cloud remanufacturing business models which based on non-mature industrial infrastructures are complex to be adopted for societies suffer from lack of infrastructures. Since the intended societies are unable of customer protection, product quality control and consequently sustainability. In this case, adoption of educational institutions based cloud close loop supply chain by remanufacturing can be interesting sustainability development approach to realize sustainable production. Sustainability of societies required sustainable production strategies for resource and environment conservation to maintain application of closed loop supply chains by remanufacturing for conservation of energy, material and value added with waste prevention and environment protection. Innovative multiple lifecycles can be predetermined at the product design stage to be applied development by remanufacturing at the end-of-life [1]. Sustainable production and remanufacturing imply meeting of the requirements for the three pillars of sustainability enhancing. Remanufacturing enhances sustainable production to certain also improved environmental friendliness, reduced cost, reduced power consumption, increased operational safety, improved personnel health and reduced wastes [2]. Sustainable production activities of optimizing use of resources through renewable energy, recycled water, inputs stemming from the recycling, recyclable outputs and recyclable wastes can certain reduction of air pollution, water pollution, land pollution, dangerous inputs, dangerous outputs and dangerous wastes [3]. Design products to be disassembled, reused, remanufactured, reduces the amount of hazardous materials using and increases biodegradable packaging which are criteria of the environmental performance level of sustainable production [4]. Total recovery cost, remanufacturing lead-time, minimization of landfill and waste and quality of remanufactured products should be optimized to reduce the negative impacts on the environment through designing sustainable products and implementing cloud manufacturing [5]. To reduce the environmental impact of products the usual reduce-reuse-recycle (3r) trilogy are insufficient to achieve the objective of sustainability, so emerging of (7r) is necessary which includes remanufacture-redesign- recover-reconfigure-reduce-reuse-recycle, such capacities can

reduce the functional obsolescence of products by updating the architecture of sustainable products. Such integrating of sustainability considerations into engineering practices instead of adding additional practices and tools is a sustainable product development through eco-design adoption which is an early integration of environmental aspects in development processes as a sustainable eco-design [6]. Closed-loop production systems and closed-loop supply chains can be achieved using different approaches and strategies to contribute both of the reduction of negative environmental impact and increasing of economic benefits. This will improve sustainability and lead to improvements in environmental performance of an organization. Closed loop, life cycle issues, end of life and total life cycle are current literature directives to help developing of sustainable manufacturing as shown in Fig.1 [7]. Closed loop product life cycle and closed loop supply chain require the application of remanufacturing activity to close the supply chain and predominate sustainable manufacturing what is highlighted through the work of [7,8]. Sustainable development, such as closed loop sustainable manufacturing, is recognized as a long-term oriented strategy to concern both current and future generations by combining short-term and long-term goals. But even long-term perspective is essential for manufacturing organizations to achieve sustainable development, analysis can show that the time perspective is taken rarely with emphasize on short-term thinking for sustainability as shown in Fig. 2 but the need to focus on both long and short-term aspects is highly required [7].

What is called Micro-Literature is a term used within this paper to show that low attention literature due to non-taken into consideration through the tested sample of published literature papers. Such literature is the most important to help close the supply chain by a non-industrial country. The most highlighted literature is called Macro-Literature which most suitable to be applied by an industrial country.

1.2 Educational Institutions based Remanufacturing Directives Proposing

Maturity assessment of literature, Fig. 3, can lead to propose part of literature to be the micro-literature of remanufacturing contribution to help emerging of cloud manufacturing of remanufacturing as a service through integration of educational institutions. Micro-literature is consisted for some extend with aim of sustainable cloud manufacturing especial in cloud remanufacturing, radio frequency identification, and Internet of Things for remanufacturing but they are not enough because technological dimensions are only highlighted. It can easily be seen that the micro-literature represents a small portion of the current scientific literature of remanufacturing for sustainable cloud manufacturing and it can be estimated that about 0.5-2% of micro-literature is responsible on cloud manufacturing of remanufacturing as a service and there is no any sign of incorporation of educational institutions within cloud manufacturing for remanufacturing within the selected sample of 100 published articles and papers. Macro-literature focuses on the economics of remanufacturing and related incentives with no sign to closed loop cloud manufacturing with remanufacturing through inclusion of educational institutions to apply sustainable development. Educational institutions based cloud manufacturing-remanufacturing system is a partial society preparation and micro-literature can be proposed to include:

- Educational institutions cloud manufacturing of remanufacturing as service enablers. Educational institutions product service system.
- Educational institutions cloud remanufacturing.
- Educational institutions internet of things.
- Educational institution based data acquisition systems application.

There are no such directives of the micro-literatures of remanufacturing and instead literature of remanufacturing includes the nearest directives which of huge weakness due to declined percentages of such directives as shown in blue curve in Fig. 3:-

- Sustainability (2%).
- Cloud remanufacturing (0.75%).
- Radio Frequency Identification (RFID) (0.75%).
- Internet of Things for remanufacturing (0.5%).

Macro-literature, red curve in Fig. 3 can be concluded to include literature directives of:-

1. Hybrid manufacturing/remanufacturing (28%).

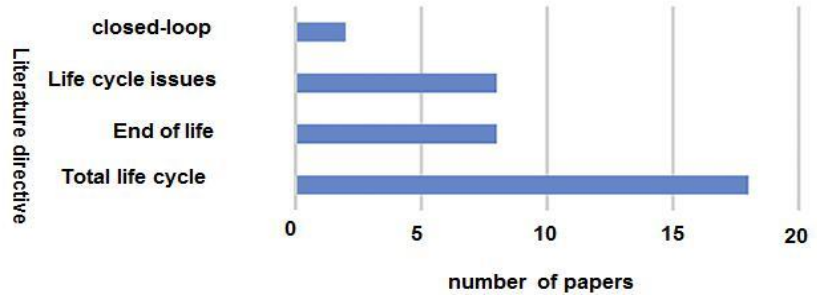

Fig. 1. State-of-the art of sustainable manufacturing [7]

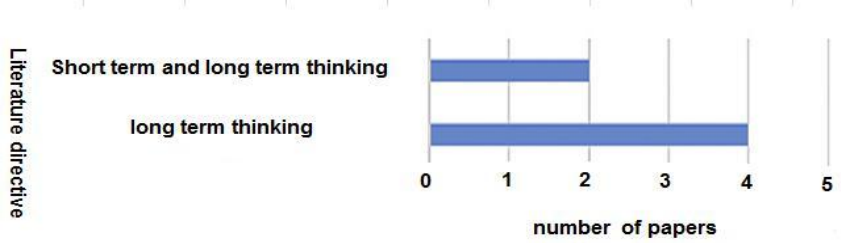

Fig. 2. Compression of long term and short sustainability thinking and short term sustainability thinking literature areas [7]

2. Cost and prices (17%).
3. Remanufacturing supply chain design (10%).
4. Stochastic uncertainty (8%).
5. Reverse logistics (8%).
6. Management, planning and timing (5%).
7. Reusing (5%).
8. Policies and customers (4%).
9. Lot sizing problem (4%).
10. Inventory problem (4%).
11. Deteriorating (3%).

It can be seen that macro-literature focuses on economic of remanufacturing without any sign to any methodology to close the loop supply chain with cloud manufacturing.

1.3 Literature Statement

Sustainable development to meet the needs of the present with keeping the ability of future needs through sustainable manufacturing of closed supply chain through closed product lifecycle can be obtained by remanufacturing. Introduction of educational institutions to be a part of global economic can close the supply chain through cloud manufacturing of remanufacturing as a service. There is very low percentage of literature is detected to sustainability that includes potentials of remanufacturing as a service within cloud manufacturing platform.

2. LITERATURE REVIEW

2.1 Findings of State of-the Art of Sustainability, Sustainable Manufacturing and Remanufacturing Reviews are

Closed supply chain of production by remanufacturing is sustainable production. • Sustainable production is triple line sustainability and development approach. • Cloud manufacturing platform with remanufacturing-as-service is closed loop supply • Chain manufacturing which combines long term and short term suitability thinking. The first step for educational institutions is the conducting of closed-loop remanufacturing, Fig. 4, to attract researchers for conducting researches to help enablers maturity.

2.2 Procedure to Stop Unsustainable Consumption

Eco-design and multiple lifecycle of products:

- Raising the value of end-of-life product by remanufacturing.

- Architectures and methodologies in fields of cloud computing, knowledge and expert systems can be exploited for useful remaining life evaluation.
- Prognostics, diagnostic, shape recognition to be delivered as an integrated platform of smart sensory, collaboration between educational institutions and industry,
- Crowdsourcing and Internet of Things to be incorporated into step by step architecting to envelop a remanufacturing as a service of cloud manufacturing model as a mass customization procedure.
- Eco-design and eco-innovation will be crowdsourced as collaboration between educational institutions and industry.

Thus pro-environmental using and sustainable consumption can be emerged to help conduct of remanufacturing which is necessary for sustainable production of closed loop supply chain. Finical incentives can induce cooperative social forces to be optimized as voluntary efforts according to maturity of society in accordance to environmental awareness and protection.

The key factor is how to realize the social contract to be the revival to pull the development of the sustainable production as a social responsibility so the sustainability can be improved when environmental innovation is applied [9,10] , such as eco-design.

2.3 Drawbacks of Recent development of Cloud Integrated Remanufacturing

- Cloud computing cannot deliver transition from cloud manufacturing to cloud remanufacturing without mature manufacturing infrastructures to include remanufacturing as a service.
- Independent cloud remanufacturing is architected at [9,10] which is not suitable to be applied in educational institutions without manufacturing infrastructures and Internet of Things bases.
- Educational institutions have no manufacturing infrastructure so special remanufacturing industry sector is not proper choice.
- Remanufacturing with Radio Frequency Identification, as example, enables optimization, waste reduction and quality improvement application [11].
- Even Internet of Things supports quality management and product recovery optimization [12], but requirement and infrastructure of bifurcations cannot be realized.
- Infrastructures of manufacturing , Internet of Things and customer protection are not well prepared to discover any hidden lowering of product value added to prompt cheap production paradigm which drives towards unsustainable behavior .
- By considering, Fig. 5, to conclude the suffering from non-extending of manufacturer responsibility to process end-of-life products. Also obviously , conclusion can state that a famous brand products with unknown manufacturer even Radio Frequency Identification tags are included since the legislations can only be applied in Europe while the product sold in different markets where no Internet of Things facilities.

2.4 Solution Package

- Since Internet of Things is not well done in educational institutions so:- •Educational institutions Internet of Things enables cloud library as big information storage of end-of-life products.
- University and Industry collaboration can be employed to focus attention of crowdsourcing to evaluate end-of-life products status and to suggest appropriate remanufacturing treatment.
- Digital ware house in the cloud can be established to certain stream of well-informed end-of-life products, imaging and CAD files can be accompanied material properties, and to link resources of industrial and educational institutions.
- Eco-design and eco-innovation can be induced crowdsourcingly to match remanufactured modules to function with new product architecture.
- Data base, knowledge base and expert base can also crowdsourcingly developed into information to strength data acquisition base.
- Adaptive machine learning can be achieved through crowdsourcing training and testing applications.
- Accumulation of expert and knowledge are urgently needed due to huge weakness in design and manufacturing conscious environment bases of educational institutions.

3. MOTIVATIONS OF CLOUD MANUFACTURING OF REMANUFACTURING AS A SERVICE SYSTEM

To get data base that enables eliminating of remanufacturing inhibitors, a bunch of motivations are needed to be constructed as following:

- Quality management and optimization by Internet of things application: Eliminating uncertainty due to variation of types, conditions and remaining lives of components of end-of-life products can facilitate planning of remanufacturing operations. [11].
- Hybrid manufactured and remanufacturing modules to produce new products: New products are manufactured base on hybridism of remanufacturing of modules from old returned items and new manufactured modules [12].
- X- Grade as a service: Physical products with associated services bring more value to final customers than the pure physical objects only without accessories and services. Cloud manufacturing systems result higher individualized and user-friendly product based on experiences acquisition and reflect intelligent and connected products throughout whole life-cycles. Product service systems merit flexibility, adaptability, reactivity, expertise, and X-gradability. Such X-gradability approach enables sustainable products and satisfaction for users' expectations by delighting with intensive engagement in product design, functionalities, services, and individual experiences. Production of personalized products can be facilitated through integration and collaboration of virtual social network, internet of things, cloud manufacturing and product service system. [13].
- Mass customization and personalization: Manufacturing and product services systems design, plan and operate globalized manufacturing networks that can encounter decreasing lifecycles, increased product complexity, mass customization and demand volatility. Cloud automated closed loop control systems are necessary to deliver technology and related businesses approaches globally and enable optimizing of enterprise performance in area of design and planning of manufacturing networks for mass customization and personalization. Through supporting and promoting of dynamic configuration and optimal routing of manufacturing networks and facilities, time, complexity environmental constraints, and product service personalization [14].

All these motivations source in a reservoir of solutions to cope with remanufacturing inhibitors which can be concluded into bifurcation of cores, uncertainty of cores quality, unclear plans of remanufacturing and labor and time consuming behavior.

4. THE EMERGING OF CLOUD RE-MANUFACTURING AS AN ENABLING SERVICE

To realize sustainable manufacturing based cloud manufacturing, priority of structure of state-of-the art of remanufacturing are proposed to help emerging of remanufacturer educational institutions , Fig. 6, which include :-

4.1 Educational Institutions Internet of Things

Virtualization and cloud computing can fulfill integration of sustainable manufacturing infrastructures to be accessible anywhere and anytime through Internet of Things which extends the cloud computing concept beyond computing and communication to include everything especially the physical devices [15]. Networked smart objects with communication, sensory and action capabilities can achieve global supply chain management [16]. Tangible benefits to the society, environment, economy and individual citizens can be certain as sustainability delivering through infrastructure of ubiquitous computing technologies and applications with various forms of sensing devices based on digital and radio frequency identification enablers[17].Information and communications technology based businesses are strong innovation networks under the management and interventionist of government to enable the successful technology catch- up and providing various financing policies and programs to develop high technology based businesses as a strategic implementation of innovation financing programs provide useful lessons for educational institutions [18].So interventionist of government development can be directed as educational institutions Internet of Things, Fig. 7.

4.2 Educational Institution Sustainable Product Service Business-education-training Model

Radio Frequency Identification application in the field of remanufacturing is taken very limited literately, and also for limited application of this technology in the aimed educational institutions in this study. So data acquisition of product lifecycle and particularly end-of-life products should be done through institutional platform under the supervision of specialists. Deliver of data about product lifecycle cannot be certain without experience which is hard to be gotten by individuals. Internet of Things has advanced to a new level with RFID to deliver intelligent sensory to be interconnections between physical devices and products which can be developed to include product lifecycle to provide enough information about end-of-life quality and how to remanufacture the modules and consequently application of eco-design to include the module within the architecture of new products[19]. But this required robust infrastructure which is not available for the aimed educational institutions in this study, so emerging of educational institution sustainable product service business-education-training model, Fig. 8, can be a promising employment of technology to support remanufacturing embedding in the cloud as a service.

4.3 Cloud Storage and Cloud Manufacturing Platform

Product lifecycle related data are stored at designated servers, and users know where these data and which manufacturing

cloud platform providing them. Networked enterprise data are stored in virtualized data centers and data can span across multiple servers. The data can be accessed through a web service application programming interface or a web browser. Cloud based data storage provides users with ubiquitous access to a broad range of data stored in the networked servers through a web service interface. Thus data storage can easily scale up and down as needed on a self-service basis.

4.4 Eco-design

Cloud manufacturing provide distributed resources encapsulation as cloud services ranging from product design, manufacturing, remanufacturing testing, management and assessing of all information of product lifecycle. Cloud manufacturing service platform performs search, intelligent mapping, recommendation and execution of a service, and thus eco-design as a service can be delivered. Equipment, computers, servers, raw materials, simulation software, analysis tools, know-hows, data, standards, employees, product design capability, simulation capability, experimentation, production capability, management capability, and maintenance capability can be exploited to remanufacture end-of-life modules and embed them within new products structure. Such all as a service, in the cloud, can easily provide eco-design which is the best method to include the taken back from landfills end-of-life to be remanufactured and used [19]. Requirements elicitation is prepared through product service systems to incorporate customers' expectations and end-of-life modules to be ready to use for design purposes. Cloud based information management tools allow for enhancing information flow management practices that can significantly improve design productivity. Such collaborative design is information driven process among design activities. Data mining and visualization technologies have the potential to significantly increase the productivity of design process by allowing searching of design data for the right design information from the right resources. Data consistency, transparent communication and seamless information sharing are aimed activities which are more cost effectively and efficiently by using cloud based design.

4.5 Sustainable Product Service system

Customer value proposition is priority through software enabled services and business oriented customer value creation. Industrial software and product service system for products, services and solution of a problem and fulfillment of needs are hybrid value creation, which characterize the overall value proposition level by customization and strategic integration, organizational, marketing, design, innovation, and business levels, sustainability aspects and the macroeconomic perspective delivery . As a consequence, fruitful collaboration processes, value creation networks, knowledge sharing and management, and business models.

- Institutes of technologies based national maintenance, repair and remanufacturing based sustainable product service system.

- Local independent remanufacturers' acquisition.
- Reveres logistics strengthening, bifurcating and enlarging.
- Eco-design, eco-innovation and design for remanufacturing are legislated to certain remanufacturability of new imported products.
- Gradual complex products remanufacturing.
- Local cloud end-of-life modules library and information system.

5. REQUIREMENTS OF CLOUD MANUFACTURING OF REMANUFACTURING AS A SERVICE [13]

1- Social media can base delivering of services that support communication, information and knowledge sharing and emerge individual service providers to enable users-customer interaction with the global community of experts and educational institution Internet of Things to exploit, utilize and leverage crowdsourcing processes in design and manufacturing.
2- Elastic cloud-based distribution and storage systems to allow ubiquitous access to design and manufacturing data, which also allow collaboration and enable automatic sharing, maintain, and synchronize of data files and instant exchange.
3- Multi-tenancy environment, web browser enables single software serves multiple tenants and provides instance software as a service application, as a cloudification of software aided manufacturing.
4- Educational institutions and integrated product service system can manage Internet of Things for collection of end-of-life and whole lifecycle information to be stored in the cloud based distribution and storage file systems, with cloudification, collected and stored real time data of workflow, availability and capacity from manufacturing resources. To allow remote monitoring and controlling planning, scheduling, and dispatching incorporated remanufacturing. Internet of things infrastructure leak substitution is necessary through educational institutions integrated internet of things.
5- Service oriented manufacturing should be adopted to provide everything as a service as an X-as-a-service within suits of infrastructure as a service, platform as a service and software-as-a-service
6- Intelligent search and quoting engines enable online suitable allocation of manufacturing resources in the cloud and quoting based on design and manufacturing specifications.

6. PROPOSED CLOSED LOOP CLOUD MANUFACTURING OF REMANUFACTURING AS A SERVICE

Proposed closed loop supply chain of cloud manufacturing, Fig. 9, through integration of remanufacturing as a service enablers Strategic business models of remanufacturing based sustainability of educational institutions should be emerged. So some primarily preparations are required such as private recycling reverse logistic of Aluminum and Plastics are integrated within national reverse supply chain by financial incentives. Public media promotion can strength this chain by satisfaction of public discussion to induce sustainable development. Education disciplines are emerged to include remanufacturing and provided practical syllabus to be achieved by student to satisfy graduation requirements. Cost/labor ratio is as low as possible due to exploit educational and social activities to substitute the labor intensive remanufacturing by green power man. Digital library can contain detailed information such as CAD files, pricing, quantity, quality, mechanical and material properties and product status. Exposure of such information to crowdsourcing and adaptive learning knowledge and expert systems internationally results into mature information about how to remanufacture these modules. A digital bank of eco-ideas can satisfy exploiting of this mature information for sustainable integration of remanufactured modules within eco-products structures through cloud manufacturing systems, Fig. 10.

7. RESULTS AND DISCUSSION

Two directives of literature can be extracted, one is the viability of remanufacturing, which freezes remanufacturing in the stage of feasibility, and the second is the exploiting of information and communication technology to close the supply chain of manufacturing through cloud of everything as a service. Also an appreciated attempted to help emerge cloud remanufacturing is offered by [20]. All of these directives did not take into consideration educational institutions, especially without industrial infrastructure,

because there are no feedbacks from such institutions. The breaking of current manufacturing supply chain should start in literature to be followed by integration of educational institutions within global supply chain. Researchers should take into consideration that employments and human development are necessary needed incentives to integrate more than two thirds of man powers which live as consumers and change their areas into big landfills. Powerful exploiting of man power can be through integration of scientific research and remanufacturing literature through integrated platform of product life cycle assessment by educational institution internet of things and cloud storage to mature the collected data. Fig. 10 shows an integration of remanufacturing literature as a tool to help educational institution internet of Things to be embedded within architecture of Cloud Manufacturing for data maturing. Thus a scientific research based crowdsourcing can be

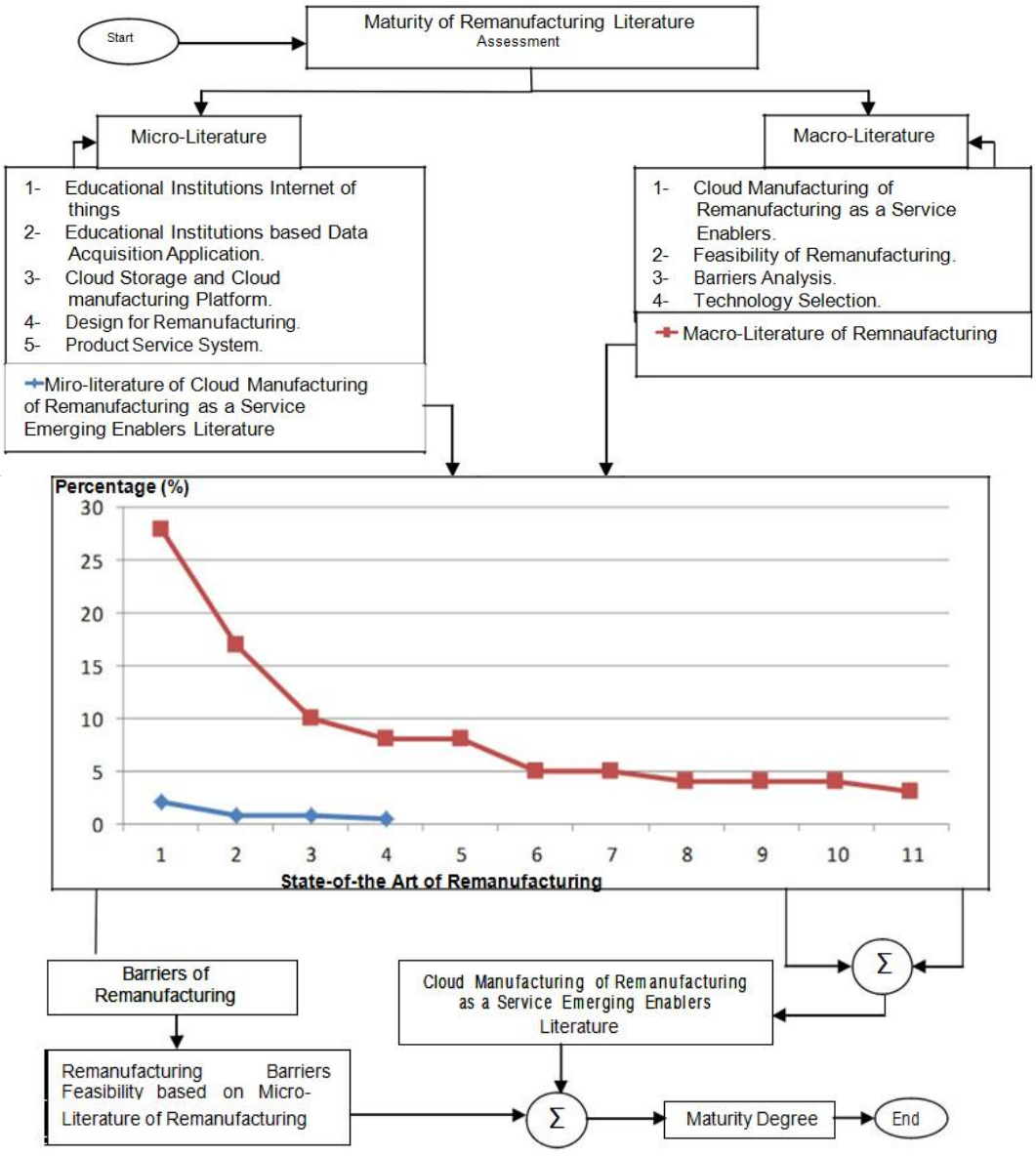

Fig. 3. Assessment of the micro-literature of remanufacturing contribution to help emerging of cloud manufacturing of remanufacturing as a service

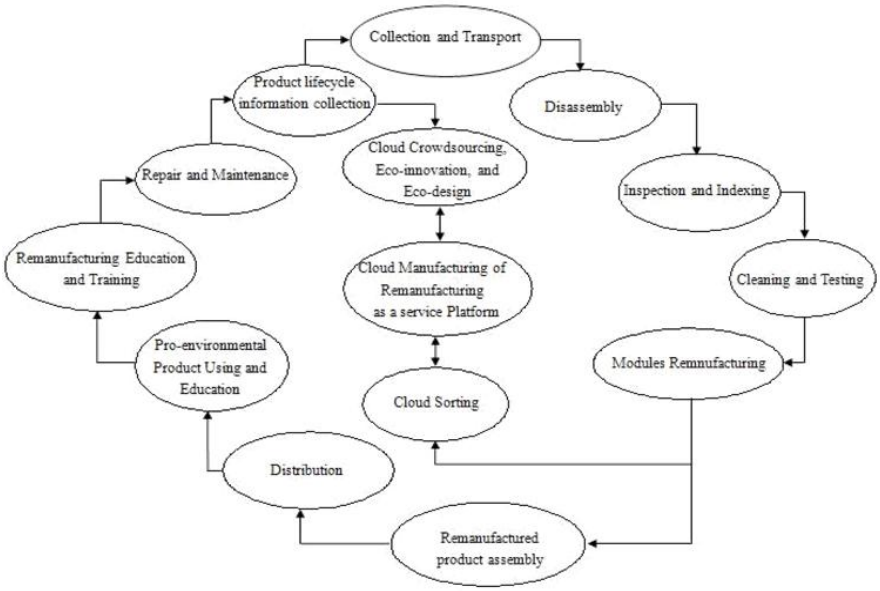

Fig. 4. Proposed closed-loop remanufacturing

Fig. 5. Illustration of non-applicability of radio frequency identification since remanufacturing limited to europe only

maintained to be applied for industrial information realizing to be more satisfied to emerge integration of remanufactured modules within new products. Fig. 11 explains how the relation should be to induce positive reaction among elements through cloud manufacturing platform to deliver remanufacturing as a service. The role of educational institution can be focused in the following points:-

- Strengthen the relation among stockholders.
- Apply life cycle assessment.
- Mature end-of-life data to be applied for remanufacturing.
- Application of remanufacturing for cloud manufacturing where remanufactured modules are used to build new products.

The role can be continued to include not only application of data acquisition where specialized staff can be certain, but also application of product service system to realize demand of customer, application of quality control and customer protection. High value-added products can be certain through including of eco-design for remanufacturing within customer demand to be delivered for global manufacturers. University and industry collaboration is also of important role in data maturing. All above can help to focus insight for clear scene of role of remanufacturing literature in accelerating societies of remanufacturing to develop and emerge. Thus this study proposes the relation among different directives of remanufacturing to show the priority of sustainability based remanufacturing for cloud manufacturing based sustainable manufacturing, Fig.12.

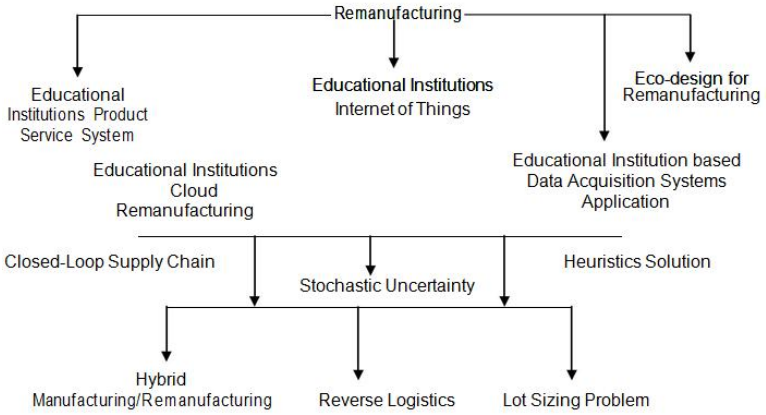

Fig. 6. Proposal of priority structure of state-of-the art of remanufacturing to help emerging of remanufacturer educational institutions

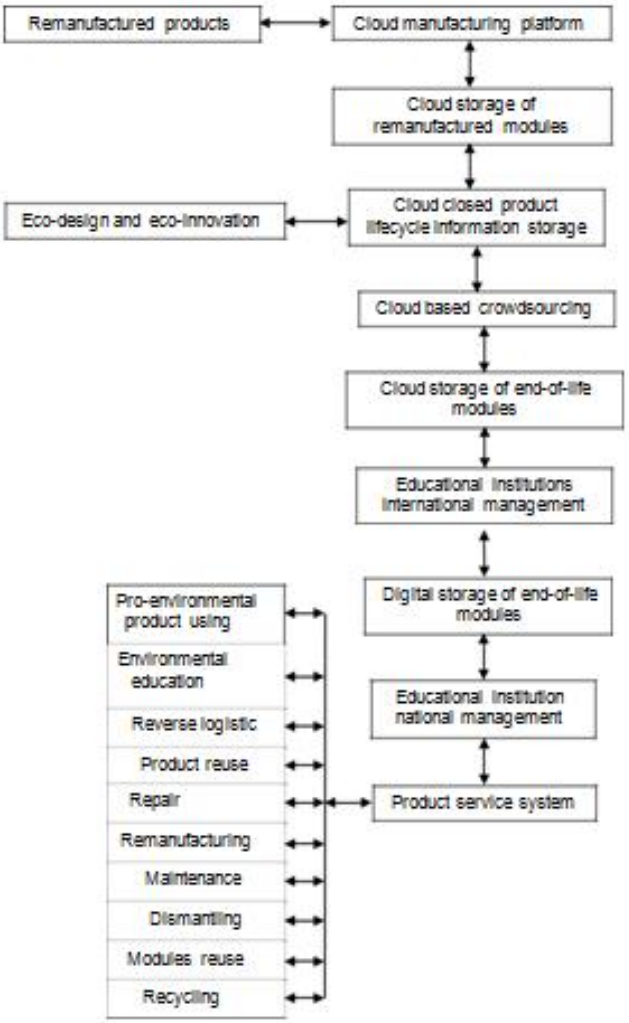

Fig. 7. Illustration of proposed educational institutions based Internet of things model

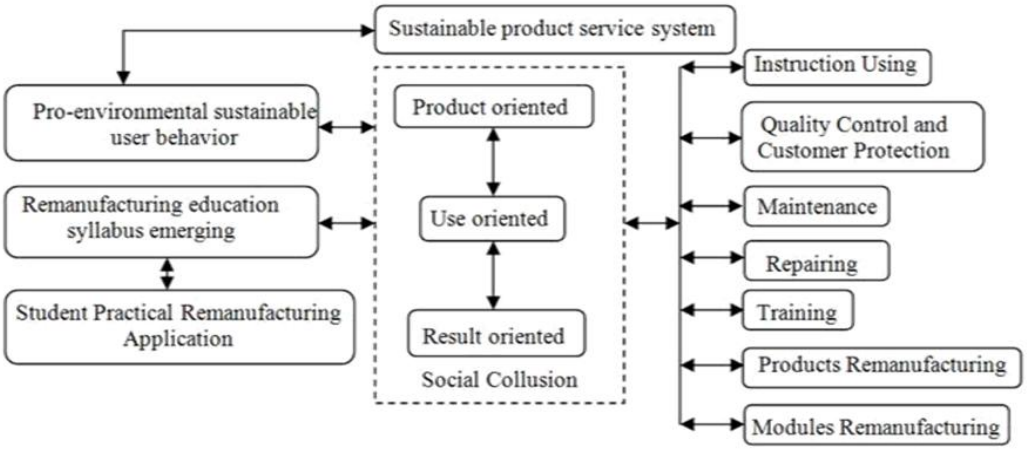

Fig. 8. Illustration of educational institution sustainable product service business-education-training model

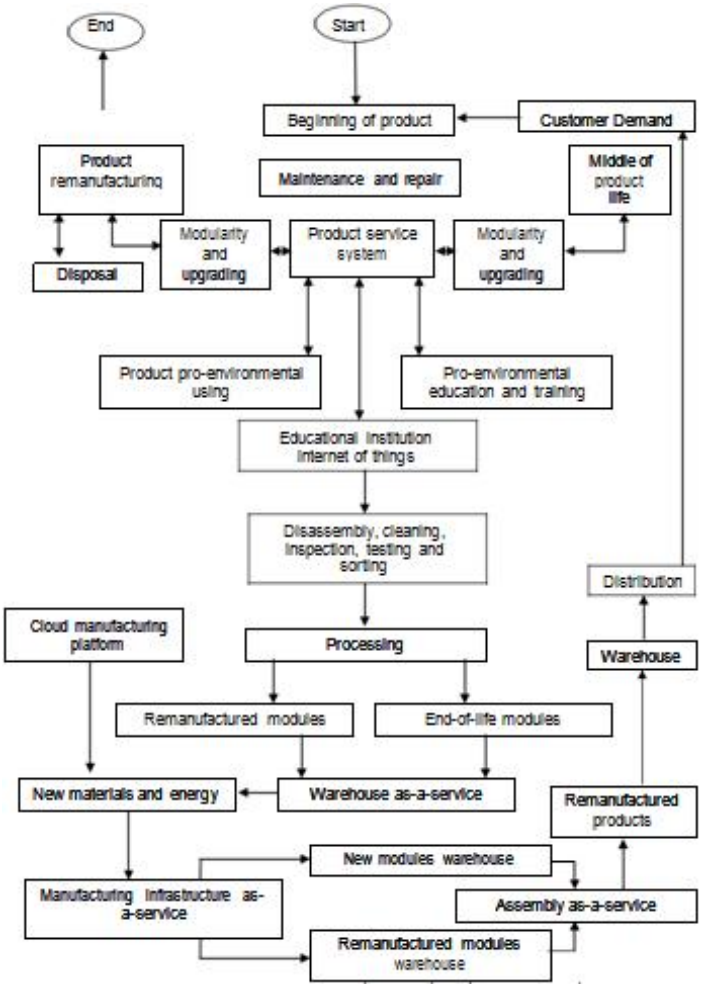

Fig. 9. Proposed closed loop cloud manufacturing integrated remanufacturing as a service

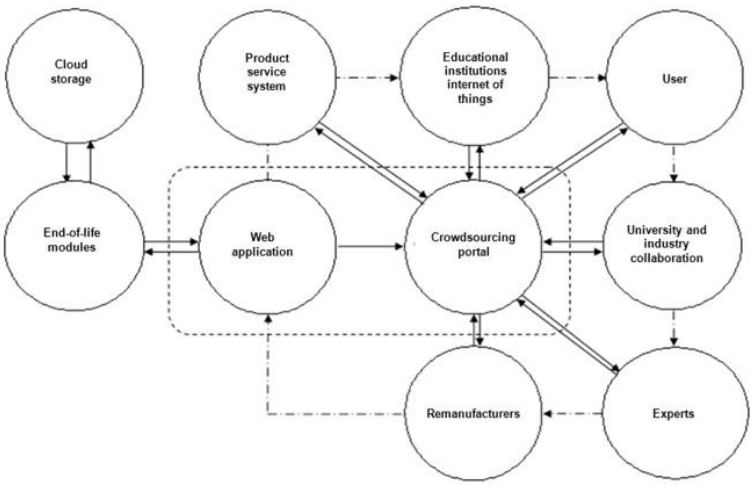

Fig. 10. Elements reaction through proposed closed loop cloud manufacturing platform to deliver remanufacturing as a service, based on [12]

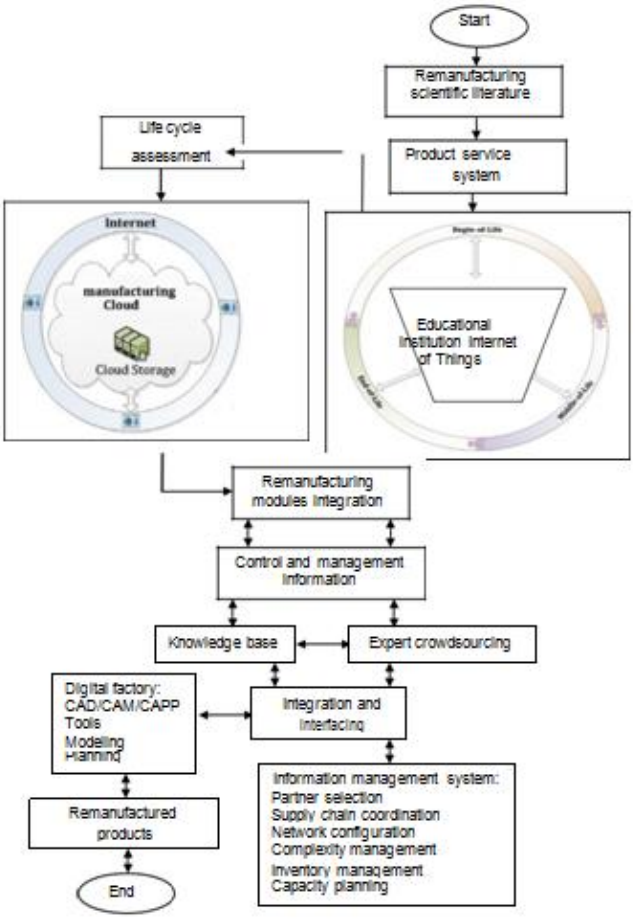

Fig. 11. Proposed integration of remanufacturing literature as a tool to help educational institution internet of Things to be embedded within architecture of closed loop cloud manufacturing system for data maturing, based on [13,20]

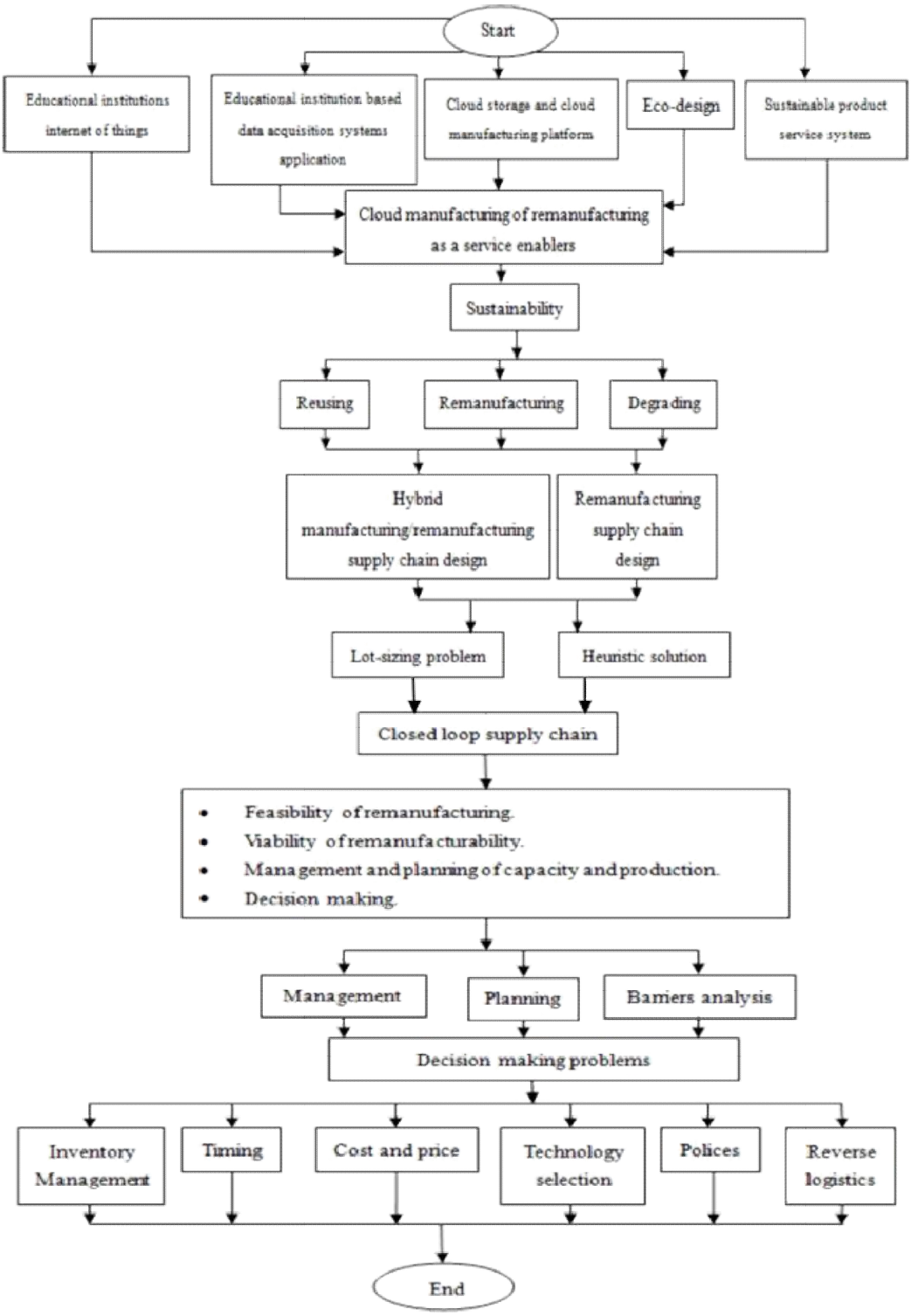

Fig. 12. Proposed remanufacturing literature directives priority to help emerging of remanufacturer educational institutions to close the loop of cloud manufacturing by remanufacturing ass sustainable manufacturing

8. CONCLUSION

To help emerging of triple bottom line sustainable cloud manufacturing based on such comparative literature study , some concluded insight points can include the following bench marks:-

1- Remanufacturing as a service can extend cloud manufacturing to include educational institutions.

2- Current global economy should be extended to include educational institutions.

3- Remanufacturing is more suitable business to cope with earth resources depletion, since it satisfies ambitions of educational institutions and industrial institutions to close the supply chain.

4- Most remanufacturing barriers and feasibility literature can be mitigated through integration of educational institutions within global economy.

5- Literature directive should be changed to generate enablers to extend not just the manufacturers responsibility but also acquire educational institutions the required remanufacturing technology.

6- Product service systems and Internet of Things are more suitable to be institutions of educational institutions under educational supervision.

7- Satisfaction of enablers as mentioned can deliver sustainable manufacturing.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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