Remanufacturing Aided Added-Value Creation, Innovations Meeting to Deliver Sustainable Manufacturing

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Abstract. End-of-life scrap steel such as vehicles bulks and bodies, steel wheel and shells are easily land filled at the end-of-life when treated in a developing country with non-industrial infrastructure. Research idea is about composite shape steel remanufacturing to be sheet steel for construction application through nested recovered pieces of scrap steel within new sheet steel base to meet innovation value creation of remanufactured steel and innovation eco-design of steel products to close supply chain through linkage developed and developing countries of non-industrial infrastructure economy. That can be satisfied through comprehensive business-education-training model conduction firstly at the developing countries to reduce costs and change the intensive labour remanufacturing paradigm collaboratively. Sustainable remanufacturing business model can be applied based on infrastructure of educational institutions such as institutes of technology to adopt environmental, economic, and social developments as triple bottom line sustainability. Such innovation value creation is driven by eco-design and eco-innovation enabling where the meet to deliver human development, employment, and education conscious environment and bench mark recommendations of development directions for upgrading to apply business that allows eco-societies to emerge, through cooperative steel scrap processing.

1. Introduction
Value creation-oriented remanufacturing copes with depletion of world resources which causes environmental and ecological burdens that lead to inevitable economic and social problems. Innovation should be focused to lengthen product use phase, sustain end-of-life processing and employ product upgradability, core availability and information flow to increase remanufacturing demand instead of to be as uncertainties that freeze remanufacturing feasibility within viability stage [1]. So dialogue and negotiation to fulfil information assessment systems and development strategies such as product service systems are required to be adopted nationally towards linked at a global level to be collaborative solutions that develop local-global sustainability [2, 3, 4]. Energy-saving and emission reduction by remanufacturing induce sustainable development which should be adopted by developing countries to substitute the lack of extended manufacturer responsibility. Manufacturer should be encouraged to supply common technical services system to know-how and learning to support design for remanufacturability and innovation. Also innovative technologies that disseminate economic and societal values to harvest high financial, societal, and environmental returns, reduce costs, increases jobs, and conserve scare resources are necessary to to practise which required global collaboration. These can eliminate consumer dissatisfaction which is due to lack of activities to include customer within design and development processes, and also lack of funding of new innovative researches and
technologies to discover uncertainties of quantity and quality of remanufactured products as a result of lack of life cycle information. Eco-design and product-service system can together satisfy customers while degrade services to relieve environmental burdens. Such efficient paradigm removes consumer dissatisfaction through integrating users' satisfaction and environmental aspects to certain technical performances through application of eco-design. Such collaborative satisfaction and balancing of customer needs and environmental aspects can degrade technical performance and maintain user satisfaction to cut down environmental impacts by negotiation through service-oriented manufacturing/remanufacturing system to sell not only physical products but also accompanied services to certain product lifecycle feedbacks. [5, 6, 7]

Sustainability statement:
Sustainable manufacturing is global closed-loop supply which starts at developed countries by eco-design and continues through developing countries by remanufacturing, where linkage in the cloud can certain flow of necessary information to deliver closed loop supply chain of flexible design to include business models, product services systems and customers as integral parts of such collaborative manufacturing. [3]

2. Eco-design and eco-innovation meeting
The following statements can show the delivering of innovations meeting through:-
1- Feedbacks of eco-design ideas can be extracted from remanufacturing of take back for remanufacturing of land filled end-of-life products.
2- Several ideas as eco-design requisitions which are mentioned in this study to keep continue steel remanufacturing.
3- Composite shape steel is eco-innovation since layers of new steel can be included recovered steel, and the sandwich configuration can be maintained through assembly with rivets and bolts.
4- Sustainable manufacturing of remanufactured steel is eco-innovation since structural steel section can be obtained.

3. Scrap steel remanufacturing motivations
   - Internet of things quality management optimization
   Eliminating uncertainty due to variety of types, conditions and remaining lives of components in end-of-life products can mitigate planning of remanufacturing operations. [8].
   - Hybrid manufactured and remanufactured modules based new products
   New products are manufactured based on remanufacturing of modules from old returned items. Remanufactured modules can be also used to remanufacture returned products to be like new [9].
   - X-Grade as a service, mass customization and personalization
   Physical products associated services bring more value to final customers than the pure physical objects without accessories and services. Cloud manufacturing systems result higher individualized and user-friendly product experiences 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 by delighting with intensive engagement in product design, functionalities, services, and individual experiences. Small series production of personalized products can be as integration and collaboration of virtual social network, internet of things, cloud manufacturing and product service system. [10].
   Globalized manufacturing networks can encounter decreasing lifecycles, increased product complexity, mass customization and demand volatility. Cloud automated closed-loop control systems are necessary to deliver technology based business 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 based on facilities, time, complexity of environmental and constraints, and product services and personalization [11].
3- Configuration of society to conduct scrap steel remanufacturing

Reduce uncertainties, eliminate barriers and supply funds and technologies for remanufacturing should be symbiotic and solidarity on both international and national levels to include products updates, eco-design and eco-innovation. Further, societies should be responding to support open research, public regulations and policies, to substitute lack of extend manufacturer responsibility, and enact subsidies for remanufacturers, to affect positively the remanufacturing business and industry. The paper explains a proposed relation between three investigated enablers to help emerge scrap steel remanufacturing which include business model, remanufacturing barriers elimination scenario and sustainability initiation key factors. These enablers interact according to the following strategies:-

1- Institutes of technologies are the bases of emerging national scrap steel remanufacturing company.
2- National independent remanufacturers’ are helped to emerge.
3- Recent private reveres logistics should be strengthened bifurcated and enlarged within national framework.
4- Design for remanufacturing is adopted as legislations which should be certain remanufacturability of new imported products.
5- Complex products remanufacturing can be conducted gradually.
6- National product services system should be established as consequences of remanufacturing maturity.
7- National cloud library and information system end-of-products are necessary to discover uncertainties and certain global remanufacturing.
8- National cloud library and information system can be linked with international cloud manufacturing systems.

3.1. Business model

Lack of strategic remanufacturing business models prevents developing countries from conduct sustainable manufacturing plans. Guidelines are proposed to help conducting of scrap steel remanufacturing business models in a developing country, based on the literature of [1] and the website http://bragecrim2.wix.com/remanufacturing[12], to include:-

3.1.1. Business Strategy: New strategy can be emerged by exploiting educational institutions infrastructures to develop remanufacturing business and seek for value creation, environmental education, employment, skills accumulation and human development. End of life products are taken back to keep continue reverse supply chain as an end of life service instead of disposal. Current private reverse supply chains of Aluminum and Plastics collection for recycling can be integrated within national reverse logistics and take back for remanufacturing, by financial incentives and public media promotion, reverse supply chain can be strengthen through public discussion about sustainable development. Education disciplines can be enlarged to include remanufacturing and provide practical syllabus to be achieved by student to satisfy graduation requirements. Cost/labor ratio can be as low as possible due to exploit educational and social activities to substitute the labor intensive remanufacturing.

3.1.2. Customer segments: High environmental concern of customer generates high acceptability of remanufactured steel which is supported by low sensible price. Functionality oriented customers should be induced as national adoption of remanufacturing business model to prompt business-to-customer paradigm to reach customization and personalization market requirements.

3.1.3. Value proposition: Convenient remanufactured steel products can be customized and of cheap price and priority. Such value proposition can be certain by standard quality and like new warranty.

3.1.4. Customer relationship: Financial based voluntary return of end-of-life products are strategic involvement of customer in remanufacturing processes and activities to apply relationship based high exchanging.
3.1.5. **Network**: Hybrid centralized and decentralized return systems can be based on current reverse supply chain of take back for recycling which can also be enlarged as private suppliers. The main emerged reverse chain is a financial based disposal, where eco-design, design for multiple lifecycle continue provide remanufactured steel as a regular switching between national and independent remanufacturers and reverse logistics operators through launching direct and indirect distribution channels.

3.1.6. **Resources**: Educational institutions infrastructure and hybrid labor of skilled and educational trainers with sustainable students’ contribution are required to perform remanufacturing of end-of-life steel into construction steel products. Such sustainable educational behavior leads to triple bottom sustainability.

3.1.7. **Revenue**: Remanufactured construction steel selling provides revenue with dynamic pricing to certain competition with imported products, so remanufactured steel should be of the lowest possible alternative price.

3.1.8. **Cost structure**: Value creation is to seek necessary minimum operating costs and drive successful continues sustainability. Symbiotic and solidarity of society are helpful to reduce labor cost while remanufactured steel selling should provide reasonable revenues to cover reverse logistics cost and rent, maintenance and buying of equipments.

3.1.9. **Financial Business Plan**: Public and educational institutions investments can start remanufacturing and profit selling of remanufactured steel can keep continue the business. While feedback form public sectors are necessary to support such adoption of human development activities. Financial assets owned by educational institution and banking leans for sustainability can drive reasonable profit of remanufacturing business.

3.2. **Sustainability initiation key factors**

3.2.1. **Financial incentives**: Since Original manufacturers are foreigner companies and new products are imported, so primarily public opinion should be enabled to response as a community sustainable conscience which leads to prepare incubator to lunch steel remanufacturing and achieve reasonable profit for business self-continue. The creation of specific rules to take into account the specificities of reverse logistics operators and educational remanufacturers, are important to increase responsibility of end-of-life steel environmental conscious treatments. Without sectorial bifurcations to avoid heterogeneous and difference of business conductors, successful educational remanufacturers and other stakeholders can be directed towards central goal of sustainability. The government releases general laws that relate to the end-of-life treatment of products. Public instructions induced community rethinking to be applied by experts as strategic end-of-life steel remanufacturing possibilities. Goals and instruments instead of compulsory laws can navigate remanufacturer from different sectors to move towards sustainability with elastic regulations to certain monitoring and feedback.

3.2.2. **Sustainable development encouraging**: Financial support can promote sustainable development, where stimulating and rewarding of remanufacturing activities fosters environmental education and public discussion on sustainable development. Advertisement and green labeling of products increase contributes to environmental education and sustainability. Such central public discussion of educational institutions and remanufacturing conductors should be actively engaged in remanufacturing activities to promote triple bottoms development.

3.2.3. **Strategies of remanufacturing**: Growing demand of remanufactured steel for rebuilding and governmental financial incentives can substitute lack of foreigner original manufacturers to enter the remanufacturing market and extend their responsibility to remanufacturing end-of-life products. Original manufacturers can provide cloud based instructions, advising and supervision even there is no responsibility toward the end-of-life products so independent remanufacturers emerge and increase.

3.2.4. **Users of remanufactured steel**: Steel consumption behavior should be reviewed and measured to introduce sustainable using. Standardizing and unifying of sustainable eco-design should be widely circulated through metal working community. Cloud metal working and e-marketing accumulate eco-steel products.

3.2.5. **Demand for remanufactured steel**: Improved quality of remanufactured steel and obey certifications and new standards as enacted by associations of steel manufacturing can certain like new
and equivalent remanufactured steel and lead to increase demand. Introducing of technologies and methods of disassembly to lower costs for remanufacturing and decrease the price of remanufactured steel should source in this direction of demand increasing.

3.2.6. Associations for remanufacturing: Certifications, technical standards and legal regulations are prompted to increase quality of products and services and cause a positive influence on demand. The aim is, associations of steel manufacturing prove that remanufacturing of steel is successful through the reduction of the overall technological gap and environmental impacts.

3.2.7. Product development: Product service system and remanufacturing can be focused to establish national service oriented value creation. This can help establishing of information bank of lifecycle of products which can be linked with cloud manufacturing to provide stream of remanufactured parts to function within new products structure. Gradual transition from direct selling into accessories services accompany physical product can configure collaborative incubator which is very necessary with eco-efficiency to apply sustainability. Services in combination with products provide higher profits and product development prospective which motivate investment to remanufacture complex products. Product service system, reducing of consumption and eco-innovation approaches integrate end-of-life products as promising environmental protection strategies to be adapted for increasing the usage and productivity of resources by enabling multiple lifecycle in different applications.

3.2.8. Providers: National Company can be established to include technical institutions in one business model to remanufacture steel and provide metal working services to produce sustainable construction steel products to be used for rebuilding of infrastructures and services through whole the country. Step by step introduction of more complex products to be remanufactured to link national cloud of remanufacturing with cloud manufacturing of developed countries can be realized. Product service system and product lifecycle related information system construction can configure strength remanufacturer-customer relationships and deliver educational environment and pro-environmental using and consumption promotion. Complete substitution services system to be included detailed information about remanufactured modules and parts can be further crowdsourcing to get mature information to be exploited for remanufacturing of like new products.

3.2.9. Qualification: Environmental education and business entities realize enormous potentials that enable graduation and training requirements fulfillment and certification which can be exploited as sustainable efforts. Educational institution with remanufacturing teaching and trainings through comprehensive business model can link, at international level, associations, universities and companies collaboratively. In addition, special training and informal education can be increased to serve with public discussions contribute sustainable development of remanufacturing. Remanufacturing business can be delivered internationally as a cloud service and thus, international experts can be exploited for further maturity of information for remanufacturing. Public promotion and offering of trainings related to remanufacturing spread wide knowledge, so cloud of know-how services can be offered by original manufacturers to help developing countries conduct development and sustainability.

3.2.10. Reusability: environmental education, eco-design and eco-innovation realize eco-efficiency and consequently prompt reusability. Brainstorming is a powerful innovation tool which can be extracted and exploited through crowdsourcing to be focused through information system that can be accompanied remanufactured products. Stimulating and rewarding can encourage attraction, fondness and interesting of human to generate eco-ideas.

3.3. Remanufacturing barriers elimination scenario

Lack of standard quality of remanufactured products and absence of organizational remanufacturers are important immaturity reasons that lead to not emerge remanufacturing due to effort illegitimacy, uncertain availability of used products, and unguaranteed quality [13], which required cloud information system. Such cloud system can enable quality and quantity of returned steel to be consistent, so continues stream of end-of-life steel is certain. As high as suppliers of end-of-life steel, strengthening of remanufacturing can be obtained while no financial based selection is applied. Final customer should be included as supplier of end-of-life steel, since reverse logistic for recycling is door to door and thus, individual returns can be collected. Storage place is enough since there is no need for
special conditions to protect end-of-steel. Responsibility toward environment protection and financial incentives can encourage conscientious responding toward society and accept rewarding few incentives. Remanufacturing problems of scattering and dispersion can be treated through social activities and public media instructions to increase awareness of environment protection. Pre-test to discover remanufacturability is no need and automation can be introduced to disassembly and reassembly. Social activities can support emerging of disassembly and assembly workshops as a responsibility toward society and environment protection. No inspection costs and no need for special inspection devices, since accuracy of remanufactured steel are consistent and obtainable. High and stable demand of remanufactured steel can help emerge of national workshops of metal working to apply eco-design and eco-innovation. Such sustainable consumption and eco-purposing of steel prompts multiple lifecycle. High acceptance of service oriented remanufactured steel can be sold with new steel through the same distribution channels to eliminate customer suspicious since quality and attractiveness are comparable with new products. Collaborative working, with skilled labor, can remanufacture end-of-life steel according to structural steel standards. Remanufactured structural steel is durable and diversity of product can be manufactured by responding to standards without utilization of high materials. Design for remanufacturing can be prompt and appear in the next generation of structural steel finished products to certain continues remanufacturing business. Structural steel products should be as simple as possible to deliver disassembly. Information banking system can expand gradually to include all remanufactured and end-of-life modules and products. Such national digital library can contain detailed information such as CAD files, pricing, quantities, mechanical and material properties, product status and remanufacturing procedures. Exposure of such information, to cloud crowdsourcing, adaptive learning knowledge and expert systems, results into mature information about how to remanufacture end-of-life modules. A digital bank of eco-ideas can exploit remanufactured modules to function within eco-products through international cloud manufacturing system.

4-Case studies and experimental procedures
Various resources of end-of-life steel can be exploited such as vehicles hulks and bodies, steel wheel and different shells and cases. Any pieces of steel of uniform shape can be remanufactured into structural steel. Such steels are remanufactured into semi-finished products which contain hollow section of tubes and pipes. Doors, windows and decoration applications need further processing of semi-finished steel by metal working operations such cutting, shearing and welding. To keep sustainable development, recent methods of consumption should be changed and substituted by more environmental conscious methods. Shapes of doors and windows should be as simple as possible and can be covered by plastics or wood for decoration and engraving purposes. Figure (1) shows an algorithm of automotive steel body remanufacturing in an academic scale. Doors , engine cover , roof and back cover are disassembly , hammered and sheared into strips to be nested within new six meters length strips to form composite shape steel. Mechanical bolting or riveting can be used to nest the recovered steel within the structure of the new strips. Energy consumed is measured and accordingly Co2 standard emission value is selected, eco-audit can be offered by figure (1) also. Different example, car wheel is illustrated in figure (4), such end-of-life steel wheels can be disassembly by turning or milling processes to remove the welded areas. Transaction cutting by plasma can certain easiness of disassembly. Consequences of bench and hand fly cutting operations can change the rim into small pieces. Hammering and shearing are series to recovery regular steel shapes, eco-audit is also recorded in figure (4). The remanufacturing of steel oil filter shells contains removing of handles, bottoms and pipes and the rest shell is sheared at one side to form long sheet by unfolding. Shearing and fit to size can help obtaining of regular recovered steel to be nested within bases of new steel strips. Since the remanufactured end-of-life vehicle is belonged to the beginning of the decade of nineties as an application of take back for remanufacturing procedure. So it is suffered from lack of disassembly due to welding and high amount of forming to be difficult to be remanufactured. Legislations makers should onset design for remanufacturing through increasing disassembly and reduce amount of forming and increase the value of used steel. The doors interior guards, figure (2), as example, are
hardened by cold forming and of several openings to simplify assembly and maintenance of door locking and windows auto open-close systems. The design makes them complex to be remanufactured and they are suitable for smelting. A feedback from the end-of-life doors can secrete an eco-design idea. Instead of one piece as in figure (3), two pieces with as low as possible forming, to avoid forming and related wrinkling which is encountered during remanufactured steel preparation, can be assembled by bolts. In this contrast, authors contacted several scrap steel processing equipments manufacturers and no ability to flatten the formed steel was discovered. Produce construction steel pipe of 22mm outer diameter and 3mm wall thickness required steel strip of 64mm width. To simulate this through the door guard of two pieces, eco-design states that the main dimensions can be roughly of 640mm each, figure(3), to produce ten pieces of 64mm width to be nested by remanufacturing within two bases of new steel of 64mm also. Finally coil of 64mm remanufactured steel can be obtained by repeating the nesting process, figure (7).

**Figure 1.** Algorithm of automotive steel body remanufacturing.

**Figure 2.** Car door’s guards which suffered from disassembly and unnecessary forming.
Car wheels steel also suffer from non-design for remanufacturing by prompting disassembly. Eco-innovation states that two pieces, figure (5), assembly by using bolts can increase remanufacturability and value embodied by the steel wheel. This will save energy consumed and needed time for welded areas removing processes. The value can be raised by interchangeability attribute acquisition, both rim and hub can be designed to be modules of storage or pipe transportation systems. Also standardization of shape and size will increase the lifecycle of the wheel and reduce unnecessary metal forming. Design for disassembly strongly appears to weak application of remanufacturing of oil cases steel. Oil flow pipes and handles are welded to main body of the steel shell which is required elimination of welded areas by mechanical processing. So such non eco-design alters remanufacturing by consuming power and time. Academic scale processing of oil filter steel cases and corresponding eco-audit are illustrated in figure (6).

![Figure 3. Eco-design idea to increase remanufacturing of car door’s guard.](image1)

![Figure 4. Algorithm of steel car wheel remanufacturing.](image2)

![Figure 5. Eco-design idea to increase remanufacturability of car steel wheel.](image3)
Recovered steel strips are mixed with new strips and since recovered steel is painted so its weldability is very low and mechanical bonding is more suitable. Aluminum rivets are strong enough to be used and self-locked pipes are another alternative. Arranging successive layers of recovered and new steels can certain new strips to be of new outer surfaces to deliver like new appearance and thus the required thickness can be obtained.

5-Conclusion
To be consistent with scientific literature which states that huge amount of vehicles are at the end-of-life each year and with directives of bigger cars manufacturers to reach 95% of recovery. This study
represents a request to take in consideration aspirations of developing countries to conduct remanufacturing business. Industrial nations can crowdsourcing eco-design and eco-innovation to certain continues stream of remanufactured steel through design high value products to continue in service until the end-of-life. While remanufacturer societies are emerged based on educational institutions in the developing countries to close the supply chain as globally integrated sustainable manufacturing platform. Remanufacturing of car body registered high required energy than the lowest which is registered by oil filter shells remanufacturing, but highly available resources of end-of-life vehicles prompts car body remanufacturing. Table (1) is a literature based comparison, [14], to show the level of embodied energy for virgin, recycled and remanufacturing steels. Such academic scale needs to be further searched to be applied in industrial scale to certain lower levels of remanufacturing energy and to apply automation at assembly level while intensive labor remanufacturing can be covered through education-business model.

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