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POLYMER MATERIALS AND THEIR USAGE IN VETERINARY PRACTICE

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Abstract: In the field of regenerative medicine and tissue engineering, the use of such materials has been included for a short time, serving not only as a replacement for damaged or missing tissue, but also as a support for the surrounding tissues and cells. Such materials should not only be passively tolerated by the cell, but should also actively promote the growth, differentiation and other processes involved in tissue regeneration. The latest approach is the use and development of bioresorbable and biodegradable polymeric materials. Such materials, with their biocompatibility, degradability and suitable mechanical properties, support the overgrowth of new tissue. The application of such materials is used not only in the human but also in the veterinary field. This study approaches the use of polymeric materials processed by additive technology in veterinary practice in several case studies. It presents not only the use of new methods of materials processing, but also an individualized approach and progress in therapeutic approaches.

1 Introduction

Polymers are considered to be the widest group of materials and therefore they are increasingly used especially in the field of regenerative medicine and implantology. Since polymers can be divided into natural and synthetic, their usage is not limited only to be a part of medical devices, equipment, invasive or non-invasive devices, but they also become the therapeutic basis itself.

Several different classes of polymers are currently used in veterinary practice, which differ in their chemical structure, synthetic methods, reaction to living organism and biodegradability. The most useful non-degradable polymers used in veterinary practice include silicone, polyurethane and EVA copolymers. Polymers such as poly(lactic-co-glycolic acid) (PLGA) and poly(lactic acid) (PLA) are considered to be biodegradable and therefore belong to the class of degradable polymers.

The process of degradation of polymeric materials is accompanied by a process of cleavage of the polymer chain, which leads to a loss of molecular weight, resulting in erosion of the material, which can be defined as weight loss of the material due to the cleavage process.

The use of degradable and non - degradable polymeric materials ranges from orthotic - prosthetic solutions, through implants to controlled drug distribution systems.

1.1 Non-degradable polymers

Silicones

The rise of silicone materials began in the 1960s, when it was concluded that they were characterized by chemical and thermal stability, low surface tension, hydrophobicity and gas permeability, resulting in their dominant position in the biocompatibility and biodiversity of materials. Nowadays, they are considered to be one of the most thoroughly tested biomaterials and are used for the production of medical devices, personalized implants, drug carriers, or as parts of invasive and non-invasive medical devices [1].

Polyurethane (PU)

Polyurethanes or polyurethane elastomers are known for their molecular structure to be similar to that of human proteins. A closer examination of the material revealed that the absorption of proteins, which is a side effect of the blood clotting process, is considerably slower or lower than for other materials. This ability makes PU an ideal material for the needs of various medical applications in which adhesive forces, biomimetic or antithrombotic properties are required.

Polyurethanes are widely used in the cardiovascular field as an insulating electrode material in the implantation of an artificial heart or pacemaker, due to their elastomeric properties, which are accompanied by toughness, tear resistance, abrasion resistance and a high degree of biocompatibility with a living organism [2-4].

Polyethylene glycol (PEG)

Polyethylene glycol is widely used in the medical, chemical and pharmaceutical industries because it is non-toxic and highly soluble. It is also considered a biocompatible synthetic, hydrophilic polyether compound that can be used in biomedical applications.

PEG is most often used as part of laxatives, where it serves as a drug carrier in the form of an inactive substance. The form and process of drug administration depends on the usage of PEG because the compound binds antibody-drug conjugates. If it is necessary to improve the systematic administration of the medicament, it can be used in the form of a coating [5].

Poly(methyl methacrylate) (PMMA)

Poly(methyl methacrylate) is commercially known as plexiglass or acrylic glass. In the field of orthopedics and surgery, it is referred to as the so-called "bone cement". It is also used for the production of aids in dental and ophthalmic practice and for the distribution of medicines. Its wide scope is due to the fact that by changing the ratios of dimethylaminoethyl methacrylates, methacrylic acid and methacrylic acid esters, it can be categorized as synthetic cationic, anionic or neutral polymer. An example is a study by Gupta et al., Which provided an overview of materials used as carriers for gastrointestinal drugs, stating that up to twenty materials are made on the basis of PMMA [6,7].

Ethylene-vinyl acetate copolymer (EVA)

EVA is a random copolymer of ethylene and vinyl acetate. It is used for the delivery of drugs in laminated transdermal systems in the form of a membrane or subsoil. Ethylene vinyl acetate copolymer has also been shown to be an effective matrix and membrane for the controlled delivery of atenolol, triprolidine and furosemide [8].

Poly(vinyl alcohol) (PVA)

PVA is considered to be a synthetic hydrophilic linear polymer whose structural properties depend on the degree of polymerization and the degree of hydrolysis (i.e. the superstructure of the two monomers) because it generally occurs as a copolymer of vinyl alcohol and vinyl acetate. It is used in the pharmaceutical and biomedical engineering industries to replace soft tissues in the field of lenses, artificial cartilage or parts of the artificial heart, due to its simple structure and properties such as non-carcinogenicity, biocompatibility, strength and adhesion. Chemically and physically modified PVA structures are used in the food and textile industries [9].

Polyether ether ketone (PEEK)

PEEK material is one of the thermoplastic polymers with mechanical properties that are significantly close to the properties of human bone. For this reason, it has been presented to the professional public since the 1990s as a replacement for conventional metallic materials in the field of biomedical applications. It is currently used in additive technologies to make hard tissue replacement implants.

The surface of the PEEK polymer is biologically inert and hydrophobic, which does not allow protein absorption and cell adhesion. For this reason, it is increasingly enriched with ceramic and other bioactive materials to improve surface properties [10, 11].

1.2 Degradable polymers

Poly(lactic acid) (PLA)

PLA is one of the thermoplastics with good mechanical properties, biocompatibility and high biodegradability. PLA is obtained from lactic acid, degraded by a hydrolysis process, the rate of degradation being determined by the reactivity of the polymer with the catalysts and water.

PLA scaffolds are used to support various cell types in applications in the cardiovascular, orthopedic, bladder, muscle, bone, cartilage and tendon applications.

To innovate the required properties, various ceramic and polymeric materials are added to the PLA material, which makes it possible to increase or decrease the rate of degradation or to improve the osteoinductive properties [12-19].

Poly(glycolic acid) (PGA)

PGA material was discovered in 1954 as the first degradable synthetic polymer. It was initially rejected by the professional public due to its poor thermal and hydrolytic stability. However, the hydrolytic sensitivity of PGA was later used in the manufacture of polymeric devices, which were indicated for decomposition in humid environments and thus in the human body. With a controlled drug delivery system, PGA can be defined as a solid erodible matrix with a controlled release rate [20].

Polycaprolactone (PCL)

PCL is also a biodegradable material, but is more stable than polylactides due to less frequent ester linkages to the monomer, which ultimately prolongs the degradation time due to enzymatic hydrolysis in the body of PCL chain fragments. The rate of degradation further depends on shape, molecular weight, residual monomer content,

autocatalysis and other factors. In general, complete degradation of the PCL polymer takes 2 to 3 years in the biological environment.

Polycaprolactone itself is characterized by a low degree of biocompatibility but excels in elastic properties together with the ability to form various mixtures, composites and copolymers make it a desired material in the creation of support structures for hard tissues and scaffolds in the field of tissue engineering [21-25].

Poly(lactic-co-glycolic acid) (PLGA)

PLGA is one of the biodegradable polymers based on aliphatic polyester, containing synthetic copolymers of lactic acid and glycolic acid. Due to its biocompatible properties and biodegradable nature, it is used for the distribution of drugs in the living organism or as a carrier for the delivery of bioactive molecules [26,27].

Chitosan

Chitosan is one of the naturally occurring polymers in hard shellfish shells. It excels in its physico-chemical and biological properties, making it an application in many fields, including the medical, food, chemical, cosmetic, water, mining and biochemical industries.

Its main disadvantage is its insolubility in aqueous solutions, which greatly limits its widespread use in living organisms. By modifying some functional groups of chitosan, it is possible to improve its solubility and thus expand the possibilities of application. Such chemical modifications produce many types of chitosan derivatives that are non-toxic, biocompatible and biodegradable. Chitosan nanoparticles improve the body's immune function and, thanks to simple modifications, are also used as drug carriers [28-32].

2 Usage of polymer implants in veterinary practice

2.1 Preclinical testing of polymer materials – Case study 1

As part of preclinical testing, the different variations of PEEK polymeric material were tested on a rabbit animal model in collaboration with University of Veterinary Medicine and Pharmacy (UVMaP) in Košice. The material was produced at the Slovak Technical University (STU) in Bratislava using the technological process of extrusion on a twin screw device (Labtech Engineering, Thailand). A total of 4 variations of materials were produced:

1. PEEK polymer without additives,
2. PEEK polymer with the addition of tricalcium phosphate (TCP); proportion 85 : 15,
3. PEEK polymer with the addition of hydroxyapatite (HA); proportion 85 : 15,
4. PEEK polymer with the addition of TCP and HA; proportion 80 : 5 : 15.

A healthy, adult rabbit weighing 4.5kg was selected for implantation. The prepared implant structures were treated with a hot air sterilizer Titanox (TITANOX S.r.l, Italy) before the implantation. During the procedure, the rabbit femurs were penetrated by using a drill. The individual defects were subsequently filled with prepared implant structures and the wound site was closed with a suture. The health status of the rabbit was observed during 12 weeks, with ongoing follow-ups at 2nd and 10th week and no changes in health status were noted. At the 12th week the rabbit was euthanized with goal to examine the results.

Based on the explanted femurs (Figure 1), it was confirmed that the PEEK polymer is a bioinert material, as there was no interaction between inserted implant and the bone, in addition the implanted structure separated from the femur. In the case of composites with the addition of ceramic materials, it can be argued that the osteointegration process took place based on observations (Figure 2) using a Stemi DV4 stereomicroscope and an AxioCam ERc5s camera (Carl-Zeiss, Germany) [33].

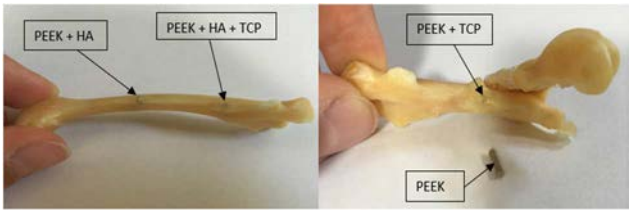

Figure 1 Explanted rabbit femurs with embedded implant structures

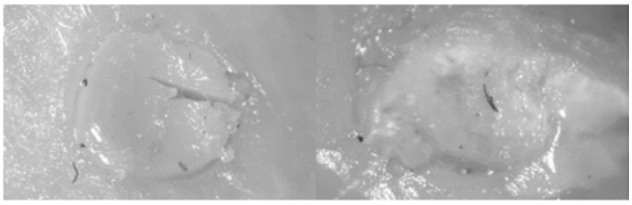

Figure 2 Stereomicroscopy at 50x zoom, the left side: PEEK polymer enriched with HA; the right side: PEEK polymer enriched with HA and TCP

2.2 Soft tissue replacement – Case study 2

Another case study that was performed in collaboration with UVMaP was a case of extensive damage to the skin layer on the front limbs of a dog. These defects also contained portions of necrotic tissue that had to be surgically removed (Figure 3).

Figure 3 Skin defects after removal of the necrotic tissue and fur

Due to the extensive damage, it was necessary to provide the bridging effect to the defect for sufficient support for the growth of emerging tissue. The implant structure was manufactured on a Deltiq2 device from Trilab company (Czech Republic). Using FFF (Fused Filament Fabrication) technology, a mesh structure was prepared from PCL and polypropylene (PP) materials in order to ensure a suitable overgrowth of the newly formed tissue, to accelerate its growth and to heal the wound.

The time set for the application of the implant structure was not predetermined and depended on the wound healing rate. Overall, new tissue was formed in 3 weeks after the application of the porous structure to the site of the skin defect, and the treated wound showed no signs of inflammatory or other reaction. After removal of the implant structure, the wound completely healed (Figure 4).

Figure 4 The left side: applied porous structure; the right side: rate of the healing process 3 weeks after implantation

2.3 Hard tissue replacement – Case study 3

Another study that was performed in collaboration with UVMaP was an adult rabbit weighing 4.5kg, diagnosed with a femur fracture. For the needs of the study, the polymeric material PEEK was chosen, which is characterized by excellent mechanical properties and chemical stability. The design of the implant structure consisted in the surgical explanting of the damaged part of the femur. For the purpose of creating a 3D model of the implant, a segment was scanned by an Identica scanner (MEDIT corp., South Korea) and the final version modeled in Meshmixier software (Autodesk Inc., USA). Implant was manufactured on a device Vshaper 270 MED (Vshaper, Poland) based on FFF technology.

The fabricated implant was surgically inserted into the defect area and anchored using a personalized fixation (Figure 5), which was made of titanium material, to ensure stability. The procedure was completed by closing the wound with a suture and administering anti-inflammatory drug treatment. The health status of the rabbit was observed during 12 weeks, with ongoing follow-ups at 2nd week and 10th week, and no changes in health status were noted. At the end of 12th week, the rabbit was euthanized, the personalized fixation was removed and explanted femur was subjected to additional evaluation (Figure 6).

Figure 5 The left side: surgical implantation of the manufactured implant; the right side: a rabbit after a successful implantation with personalized fixation

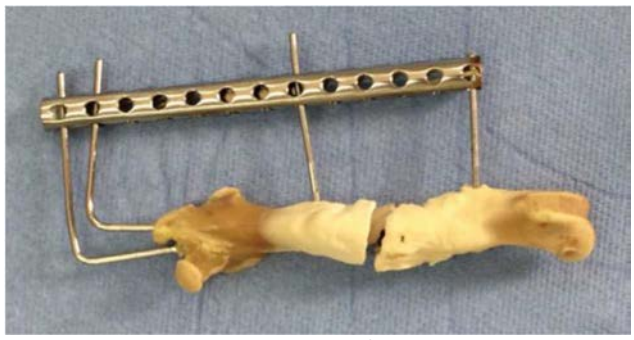

Figure 6 Explanted personalized fixation with overgrown implant strucure

The hypothesis of implant overgrowth could not be confirmed, as it can be seen in Figure 6, the osteointegration process did occur, but the implant itself did not interact with the bone tissue. Instead, the implant was overgrown by bone callus which confirmed bioinert properties of the PEEK polymer material [33].

2.4 Soft tissue replacement – Case study 4

Another use of polymeric materials processed by 3D printing technology was the production of an implant for a dog diagnosed with a traumatic tracheal defect. The dog was admitted to the UVLaF clinic, where he underwent basic clinical examinations. Given the location and extent of damage to the tracheal rings and surrounding structures, the nursing staff concluded that the use of traditional treatment options might not be successful. For this reason, the idea of using 3D printing to remove such extensive damage has been adopted. The aim of this case study was to create a personalized tracheal implant based on data obtained from a CT scan so that the original respiratory function could be restored. The therapeutic procedure was divided into two stages:

First stage (habituation) - creation of a temporary anatomical implant made of PMMA material using PolyJet technology (Figure 7), for temporary closure of the defect, but not the entire wound.

The second stage - involved the removal of the temporary implant and its replacement with an implant from biodegradable PCL material (Figure 7), manufactured on a Bioplotter (Envisiontec, USA). Surgical closure of the wound and surrounding soft tissues also occurred at this stage.

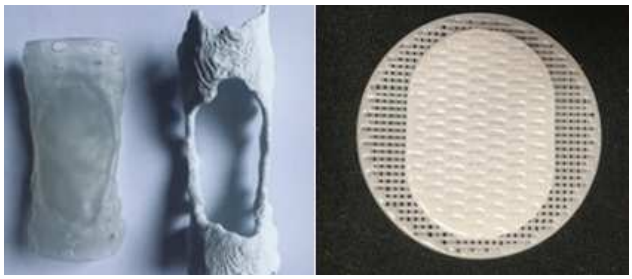

Figure 7 The left side: a temporary implant of anatomical shape that was implanted in the first stage; the right side: a biodegradable implant applied in the second stage

Several days after the insertion of the temporary implantation structure, signs of implant detachment were observed in the dog, accompanied by massive seceration of the subcutaneous structures and significant mucus deposition on the inside of the defect (Figure 8). After the six days, the polymer implant had to be surgically removed and the defect was subsequently covered with a biodegradable implant, slightly extending beyond the surrounding tracheal rings.

Figure 8 The left side: a temporary implant covered with mucus; the right side: an inserted biodegradable implant

Eight months after the primary implantation, the dog underwent a native CT and endoscopic examination, which showed that the tracheal defect healed to the full extent, with no clinical signs of upper airway damage observed throughout the dog. Despite the severity and extent of the defect, biphasic implantation has been shown to be successful.

2.5 Soft tissue replacement – Case study 5

The last study that was performed with cooperation with UVLaF, where a domestic pig was diagnosed with a tracheal defect. Based on previous experience, only a porous implant structure was used for the case, without the application of a temporary anatomical implant.

The implant was manufactured from PCL material, which was processed in the form of pellets in a Filamentmaker (3DEVO, the Netherlands). The produced filament with a diameter of 1.75 ± 0.05 mm was subsequently used for the production of an implant on a 3D printer Deltiq 2 (Trilab, Czech Republic), which works on the principle of FFF technology. The implant was designed in Magics software (Materialize, Belgium) and consisted of 4 porous layers to support the growth and adhesion of the newly formed tissue.

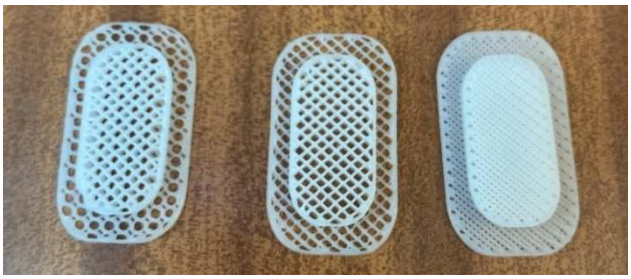

Figure 9 D

Prior to surgery, the implant was sterilized with high percent alcohol because damage to and fine deformation could occur when placed in a sterilization device due to the high temperature. After insertion of the implant at the defect site (Figure 9), the wound was completely closed and the pig was given anti-inflammatory drug treatment.

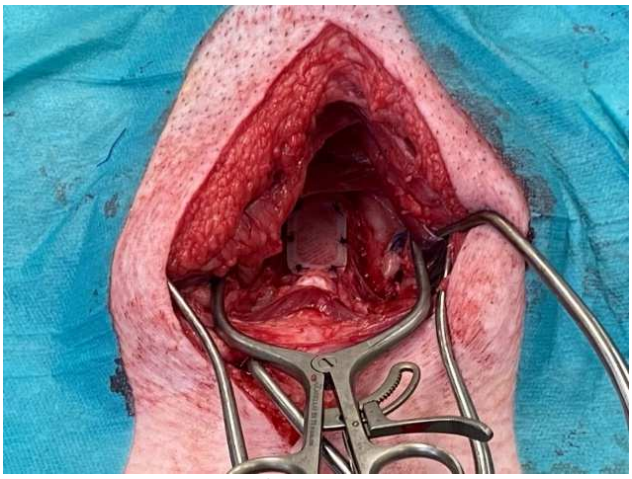

Figure 10 Application of a porous tracheal implant in a pig

More comprehensive results from the case study cannot be provided due to the fact that the study is still ongoing.

3 Results

The implementation of case studies on rabbit models confirmed the bioinert properties of the polymeric material PEEK, which is characterized by excellent mechanical properties and resistance to degradation, but biologically due to its hydrophobic surface does not support protein absorption or cell adhesion. In the case study of composite materials made of PEEK polymer enriched with bioactive ceramic materials HA and TCP, a course of osteointegration between the inserted implant and the rabbit femur was observed. Based on this observation, it is possible to confirm the influence of ceramic materials in the process of bone defect regeneration. In case studies performed on dog models, the application of porous structures made of polymeric PCL material managed to create an overlap of defects (in the case of the tracheal implant, there was a restoration of respiratory function as well) and was provided sufficient support to the emerging tissue which speeded up the regeneration process of damaged tissue. In the case of a study performed on a pig model, a tracheal defect was also covered with a porous

implant structure made of polymeric PCL material, to restore anatomical respiratory function.

4 Conclusions

In medical applications, the use of polymeric materials is quite common. The combination of standard procedures and new technologies creates new therapeutic possibilities in regenerative medicine and tissue engineering. Polymer processing technology is currently focused on 3D printing. And it is the connection of this technology with new materials that creates an individualized approach in human and veterinary medicine. Testing this synergy on animal models significantly pushes the imaginary boundaries of standard procedures in human medicine.

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SUSTAINABILITY AND INNOVATIVE LOGISTICS RELATIONSHIP WITH 3PLS PERFORMANCE IN MALAYSIA'S MANUFACTURING SECTOR

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Keywords: Third Party Logistics, innovative logistics, sustainability.
Abstract: The advent of SPV2030 and global Sustainable Development Goals (SDGs) spurred many countries into action to meet up with the national and global requirements as highlighted in the national and Global policies. Malaysia desires to achieve SPV2030, and it demands the cooperation of all sectors, including logistics, especially, Third Party Logistics companies and the Manufacturing sectors. Furthermore, it has been a great challenge to the world as the whole earth experience global warming. Therefore, all efforts are demanded to reduce or minimise the earth's warming. In line with these two important policies, SPV2030 and SDGs, this research study examines the influences of sustainability and innovative logistics on 3PLs performance in Malaysia's manufacturing sector. This study utilised a quantitative research method by preparing a good, structured questionnaire survey using systematic random sampling. About 333 copies of the questionnaire were distributed electronically, while analysis was done on 229 questionnaires, estimated as 69% of the total questionnaires. SPSS version 20 was used as software for the statistical analysis. The findings show that using innovation in green logistics as a moderation factor in the relationship between 3PLS service providers and key performance is significant. This fulfils the SPV2030 strategic thrust number 2 that Malaysia is to build resilient key new sectors. Furthermore, the findings on innovative green logistics also moderate the relationship between packaging services and operational performance, and this also fulfils a cardinal Sustainable development point goal.

1 Introduction

Issues of environmental preservation have become a subject of great concern for governments, people in society, business stakeholders and organisations. Environmental challenges like ozone depletion, global warming, air pollution and solid waste, and business organisations, particularly manufacturing firms, are considered major sources of environmental challenges. In Malaysia, the manufacturing sector is one of the major contributors to the economy's growth, but unfortunately, it has been the cause of environmental deterioration (DOE, 2010). This is because their line of operations yields more emissions when compared to other industries in the process of fulfilling consumers' needs (Rozar, Mahmood, [1]. This needs to be checked adequately, and a research study that deals with the green logistics of 3PLs providers is important.

Based on the growth of the global economy and the global supply chain network, the logistics network has become more ambiguous and is located distantly. The distance covers to determine the number of emissions resulting in larger environmental challenges. The affix, "Green logistics", is a novelty, and it is connected to planning and the logistics flow by integration of modern techniques of logistics with the main focus of minimising the hazards to the environment. The logistics flow should also be to the customers' satisfaction and the organisation's goals, coupled with the main focus of reducing the influence of these actions on the environment. Hence, as a novel idea, green logistics is the organisation's potential to deliver services and products in a friendly environment along with an efficient economy.

In Malaysia, the traditional green notions are usually linked to some challenges and weaknesses. For example, an approach such as the end-of-the-pipe method does not eliminate pollutants but transforms them from one material medium to another [2]. Another issue is that the focus on green practices within an organisation may expose it to the unpleasant environmental act of other organisations within its supply chain. For example, the small supplier's eco-friendly performance can negatively impact other purchasing companies' image and performance [3,4]. Also, the stakeholders at the community level often find it difficult to make a distinction between an organisation's environmental procedure practices and its suppliers'

environmental procedure practices [2]. Therefore, investigating the moderating impact of new innovation practices in 3PLs logistics operations is necessary.

2 Literature review

2.1 Third-Party Logistics and outsourcing

The Third-Party logistics service providers (3PLs) concept is a result of the necessity to get another party to manage the task of logistics services on behalf of particular organisations. The whole thought is to allot main logistics workloads to another person who can handle it more efficiently and efficiently. That is, the manufacturer focuses more on the core competency functions and gives room for other organisations to transport their produce to the end users, the customers. As a result, many manufacturing companies have been enjoying the benefits of outsourcing logistics functions. This includes, among others, operational efficiency, enhanced service level, greater flexibility and permitting manufacturers to concentrate on their core business since the benefits of logistics and transport can be obtained [5].

Several manufacturing companies have practised 3PLs' concepts, but there is still a knowledge gap in the Face-to-Face explanation on 3PL operations among customers and suppliers. Hence, there are still rooms for efficiency enhancement and relationship marketing which could result in the long-term breakeven of both the end users and 3PL service providers.

There are several benefits from outsourcing practices as opined by past researcher such as [6], where by it was established that above 83% of the organisation engaged outsourcing system recorded a significant drop of their purchasing cost, then, more than 73% recorded transactions cost saving, while more than 60% were enable to bring down their procurement and sourcing cycles. In the research conducted by [7], this assertions was corroborated when he explained that most significant reason highlighted for sourcing is reduction of cost and that 30% of outsourcing plans were not approved for continuity because of failure to meet the targeted cost reduction level.

2.2 Third Party Logistic practices in Malaysia

Malaysia's determination to move in line with realising a regional hub for included logistics services will eventually serve as a boost to logistics industry. There are high level emphasis given to transport and logistics industry in the 11th Malaysia Plan (2016-2020). The strategic area of concentration are majorly on the development of logistics, transport and supply chain management sector to enhance the efficiency, performance and productivity at every local ports and series of logistics operations. Aside this, there have been allocations in a massive form to further improve the systems of information systems to back up the sector. The perception, in the offing, is to enhance Malaysia's ranking in World Bank Logistics Performance Index in the nearest future. The ranking was conducted among 160 countries and it shows a marvellous upgrading from 2013, which was 29th position and in 2014, which was 25th position.

Likewise, in a research survey conducted by [8] in Malaysia, it is established that manufacturing company prefer the engagement of co ntract logistics and transport services whereby around 67.7% of the manufacturing companies samples in Malaysia, in this research scope, it is local operations.[8]. The concentration is differs for other countries, in which 3PLs sector is more of international standard focused[9]. As there is growth of manufacturing companies, there is a surge in the need for logistics support. All manufacturing companies, operating in Malaysia, both multinational and local companies, is mandated to experience high level development in the Asia Pacific region, and at a yearly compounded level of growth rate of 12.93%. This led to the growth of the marvellous growth in Malaysia's logistics sector. In the publication submitted by Global growth consulting company [10], it is significant to note that Malaysia is ranked among the first four in the World Logistics Sector.

2.3 Sustainable logistics

Sustainability was defined by Brundtland Commission from 1987 as" *the development that meet the needs of the present without compromising the ability of the future generations to meet their own needs*" [11]. It can be deduced from the definition that the development is mainly sustainable when environmental and social development are put side by side with economic growth. In the literature of logistics, the last years have witnessed quite an increase in the research publications related to logistics and transport industry in connection with sustainability, for instance [12,13]. The research varies from literature reviews and conceptual discussions on the interpretation of the term relatively to logistics context [13,14] to examine how decisions on various level of hierarchy within a system of logistics which may influence the sustainability system [15].

Although, it is usually argued that different parts of the triple bottom line, such as environmental, economical and social perspective [16], supposed to be put into consideration. Several researches on business is particular with environmental perspective in connection with more of the traditional economic perspective [16]. In the community of logistics , the research on the intersection has been marked green logistics [17] and research on the concern topic is about multiple logistics matters examines from the perspective of "green technology", which includes, among others, network structure [18], e-retailing [19] third party logistics service providers [20], as well as lean operations [21]. Logistics management is the section of supply chain that highlight plans, the implementation and controls the efficient, successful forward and reverse flow and goods storage, services and connected information between centre of origin and the consumption origin so as to meet the requirement of customers (CSCMP, 2011), "green logistics" can be observed as having similar

objectives while concurrently reducing environmental influence from the operations. Therefore," green logistics" implied a system of logistics which is designed not only to be environmental friendly, but also economically efficient [22]. In this vein," green logistics management signify organisational potentials to resource conservation, minimise waste, enhance operational efficiency, and satisfy the social expectation for the protection of the environment [23]. Therefore, this study aims to investigate influence of innovative logistics and sustainability on the 3PLs service producers. Based on literature**,** the following hypothesise were developed:

H1a. Innovation on Green Logistics as a Moderating Effect on Logistics Services and Services Performance

H1b. The degree to which sustainability is part of 3PLs and manufacturing organisation's strategy significantly influence the work amount done in the process of greening the transportation process.

3 Methodology

The method of research employed in this study was quantitative research study and it follows the highlighted procedure in [24].

3.1 Data collection

A questionnaire survey was the key data collection tools. In this study, 333 senior staffs and managers were respondents. The empirical data was gathered and collated using a web-based survey. The completed and returned questionnaire was 256 and this mark about 77% approximately.

3.2 Findings and discussion

Respondents' demography

The gender results shows that male respondents is more than female respondents. Figure 1 shows that male respondents are more than the female respondents.

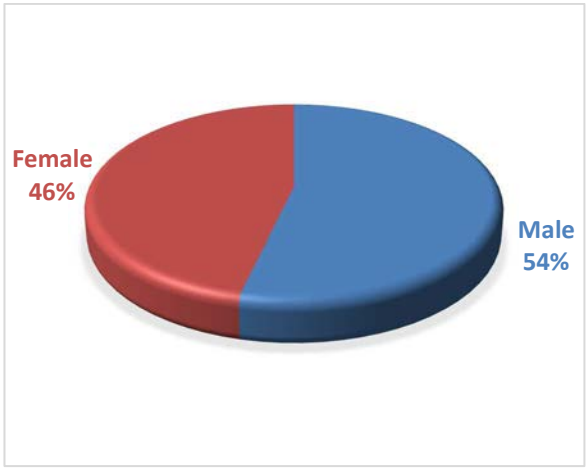

Figure 1 Respondents gender

The respondents ages are in ranges and the result shows that those respondents in the age ranges from 26-35 years while those on the ranges of 18years to 25 years recorded the second. The result is shown in Figure 2.

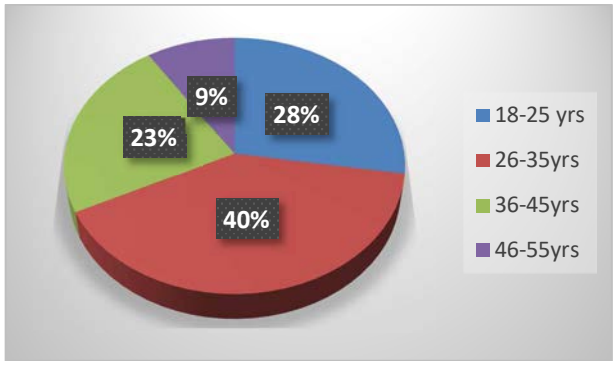

Figure 2 Respondents age ranges

The qualifications of the respondents are shown in Figure 3. More of the respondents are graduates.

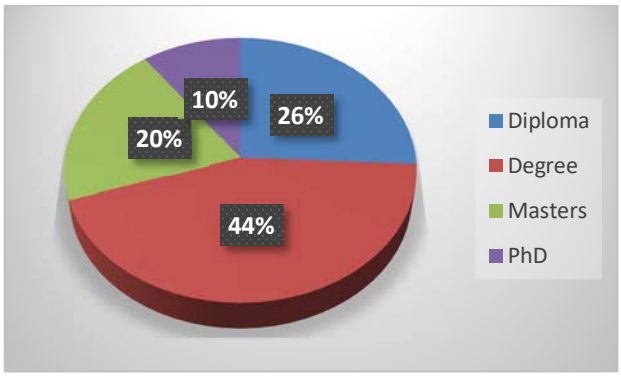

Figure 3 Respondents qualification

The individual position of respondents are shown in Figure 4. It shows that most of the respondents are others in their respective companies. Following this, are the executives of various companies. The least among the respondents are planners.

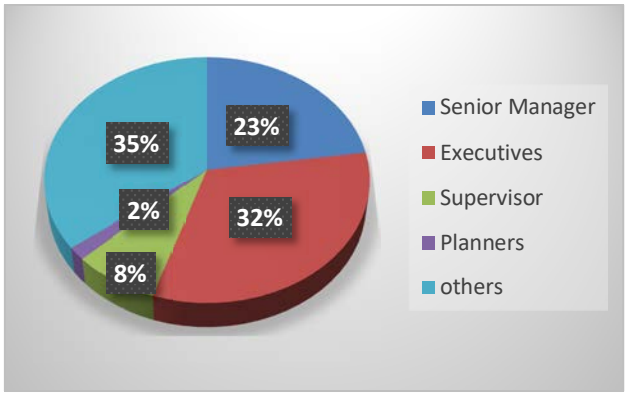

Figure 4 Respondents position

4 The findings about green logistics moderations on 3PLs performance

4.1 Innovation on green logistics as a moderating effect on logistics services and services performance

Table 1 shows the result of the hierarchical regression between logistics services and services performance. Thus, examining of the interaction of transportation services with innovation of green logistics revealed (t = -1.700; p = 0.091). This indicated that innovation of green logistics does not moderate the relationship between transportation services and services performance. Thus, the hypotheses H_{1a} is not supported. Based on the interaction terms of warehousing services innovation of green logistics, the result of the hypotheses showing (t = 2.588; p = 0.010). This indicated that innovation of green logistics moderate the relationship between warehousing services and services performance. Thus, the hypotheses H_{4b} was supported. In addition, examining of the interaction of inventory management with innovation of green logistics revealed this, (t = 2.416; p = 0.016). The result indicated that innovation of green logistics moderates the relationship between inventory management and services performance. Thus, the hypotheses H_{1b} was supported. However, examining of the interaction of packaging services with innovation of green logistics revealed (t = -1.183; p = 0.238). This indicated that innovation of green logistics does not moderate the relationship between packaging services and services performance.

In all the services performance considered, it can be established through the result that innovation of green logistics does not moderate the relationship between transportation services and service performance. On the other hand, it moderate the relationship between inventory management and service performance. This may be as a result of the transportation system that can be moderated by the introduced innovate green logistics whereby the vehicle used for transportation and logistics can be carbon free, hence be environmental friendly. It can assist it minimising the rate of carbon produced and emitted by the type of vehicles used in the transportation and logistics operation. This is also in compliance with the sustainable features. On the other hand, the inventory services is also moderated by the innovative green technology, whereby paperless techniques, ICT incorporations can be in the procedures. Likewise, the procedure of adequate reduction in time wastages and general wastages of services and products are part of parameter for sustainability. Whereby, they all discussed about innovation and learnin, customer integration, operational performance and business performance.

Meanwhile, it was observed that innovate green logistics does not moderate the relationship between packaging services and services performance. This relationship was not supported. This may be because the packaging process is the key responsibilities of the manufacturing company and not that of the 3PL service provider.

Table 1 Innovation on green logistics as a moderating effect on logistics services and services performance

Indirect Hypotheses	B	t	Sig.	Decision
Interaction Transportation-<Inn->service performance	-0.094	-1.700	0.091	Not moderated
Interaction Warehousing ->Inn->service performance	0.134	2.588	0.010	Moderated
Interaction Packaging ->Inn->service performance	-0.056	-1.183	0.283	Not moderated
Interaction inventory -> Inn -> service performance	0.124	2.416	0.016	Moderated

5 Conclusion

In summary, it can be deduced from the outcome of the result that interaction terms of warehousing services with innovation of green logistics indicate that innovation of green logistics moderates the relationship between warehousing services and financial performance. Also, the interaction of packaging services with innovation of green logistics showed that innovation of green logistics moderates the relationship between packaging services and financial performance. Meanwhile, the interaction of inventory management with innovation of green logistics revealed that innovation of green logistics moderates the relationship between inventory management and financial performance. All these findings about the influence of green logistics on the services and operations of 3PLS service providers shows a significant and positive impact on their performance relatives to some their operations. Hence, this is supported by past researchers outputs as this outcome has been corroborated and juxtaposed the adoption of green practices to adoption of technological innovation process [25-27].

In line with the government policy SPV2030, this study's findings in the perspective of making innovation in green logistics as a moderating factor in the relationship between 3PLs service provider's key performance factors and green logistics in the Manufacturing industry of Malaysia. Hence, it fulfils one of the key economic growth activities or operations under strategic thrust 2 that Malaysia is to build resilient key new sectors in both renewable energy and green economy.

Likewise, with Sustainable Development Goals, this research output in innovative green logistics which moderate the relationship between packaging services and operational performance. This goes to show that the result is beneficial in the area of fulfilling one of the cardinal points of sustainable development goal, goal number 8 to

be precise. Where it was stated that SDGs promote economic growth that is sustainable with higher level of technological innovation and productivity. The goal is to attain productive and full employment with decent work for all men and women by 2030.

This study recommends that future research can look into this topic using qualitative method and also includes all the logistics and supply chains responsibilities of 3PL service providers. The performance measurement of the 3PL service providers can be taken care of in the light of green logistics.

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COST, TRANSIT TIME, AND GHGS EMISSIONS MINIMISATION OF FREIGHT TRAINS: APPLICATION OF Q-LEARNING AND GENETIC ALGORITHM

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Keywords: integer linear programming, genetic algorithm, Q-algorithm, railway network, transportation planning.
Abstract: The purpose of this research is to address the multi-objective problem of minimising overall cost, transit time, and CO2e emissions in Pakistan's railway system. A multi-objective problem is designed using integer linear programming and reinforcement learning. This study is generally applied to transportation network design and planning challenges that need balancing various objectives. Integer linear programming is used to design a multi-objective problem, and reinforcement learning is used to identify the shortest path for a railway network. Pareto front solutions are also generated using the genetic algorithm. Using the Q-learning method, we estimated and analysed the cost, time, and greenhouse gas emissions of current and future railway networks. According to our findings, the shortest railway track connecting Pakistan's provinces of Punjab and Sindh outperforms the current railways (Fareed Express) in terms of cost, time and emissions. A cost, transit time, and CO2e emission reduction of 13% is possible when compared to the existing railway line.

1 Introduction

Freight mobility is crucial to a country's competitiveness, growth, and regional integration at the global scale. A well-developed transportation system provides for efficient and cost-effective freight transit from origin to destination. To handle such freight operations, numerous modes of transportation are provided, including road, railway, aviation, and pipelines. However, the two principal modes of inland cargo movement in the country are highway and railway [1,2]. The train has a particular benefit over transportation in terms of long-distance and large-scale traffic activities. Furthermore, rail transit causes less damage to the environment than truck transportation [3,4]. The railway transportation network of a country facilitates trade and commerce, reduces transportation costs and congestion on crowded roadways, and promotes regional integration and infrastructure development [5]. The demand for rail freight is a critical part of railroad operations. Rail freight transportation networks are created in the same manner that companies create demand for labour, power, and other resources. Freight transportation is generally viewed as an input to a company's manufacturing process, and it is obtained from demand for goods that are produced in different locations. Demand for rail freight transportation is influenced by a variety of factors, including economic activity and cost [6,7]. The primary goal of freight rail transportation demand analysis is to identify the principal elements that influence rail freight demand so that rail transportation strategy and demand management may be implemented. Policymakers, transportation planners, public agencies, and transportation operators can utilise empirical elasticity studies to analyse alternative policy choices for restricting future rail freight transport expansion, modal switch, or decarbonization. Furthermore, making policy decisions such as price control, subsidies, and taxes requires an accurate assessment of the empirical rail freight transport demand model.

Along with the importance of rail demand, international multi-echelon freight networks become intermodal transport when many modes of transportation are joined. These networks are made up of a variety of highly linked logistical networks, each having its own transit times, distances, operating costs, and transportation emissions. One of the most challenging tactical and operational challenges is the network infrastructure architecture [7]. Service network design formulas create the transportation plan to guarantee that the logistics chain runs smoothly, that demand is met, and that profitability is maintained. This is done through network-wide operations planning, which includes choosing and organising transportation services, integrating terminal activities, and regulating material movement across the logistics system [8]. The network design issue, on the other hand, is one of the most challenging problems in combinatorial optimisation [9] and The issues are caused by the system's unique interplay of parts and competing needs. This tactical-based decision issue includes the supply chain design, mode and storage selection, route description, and route elements to be employed such as shipping frequency and the number of

intermediate transhipment locations, distribution assignment along the routes, and terminal operations. Because of the system's unique interplay of components and conflicting criteria, difficulties occur. The design of the distribution network, mode and capacity selection, route definition, and route characteristics to be employed, such as transportation frequency and the number of intermediaries [10-12].

For the distribution networking, the Pakistan Railway (PR) was established in 1861 as a state-owned Pakistani enterprise based in Lahore. It is responsible for organizing and operating passenger locomotive services, as well as regulating railway firms, industries, and allied organisations, and reports to the Ministry of Railways. The PR encourages passenger and freight travel across the United States. It links the country's hinterland to coastal and dry ports (Karachi and Bin-Qasim). It also makes revenue by carrying various commodities such as petroleum oil, corn, coal, fertiliser, limestone, industrial and imported products, and so on. The Pakistan railway's effectiveness has deteriorated over time as resources have been diverted to the expansion of the road network. As a result, its proportion of inland passenger traffic has decreased from 41% to 10%, while its part of freight traffic has decreased from 73% to 4% [13]. Recognises the significance of rail for transportation, Pakistan's government has set a goal of increasing rail's share in the country's Vision 2025 from 4% to 20% [14]. Rail freight transport is measured in total tonnes (millions) and ton-kilometres (millions). In 1997-98, PR transported 5.97 million tonnes and 4447.3 million ton-kilometres of freight, which has now increased to 7.23 million tonnes and 6187.3 million ton-kilometres after a decade. The majority of the success throughout this time period may be attributed to PR's development programmes aimed at improving its services [5]. However, following 2008, the performance of public relations began to degrade, particularly between 2010 and 2013. Because of ageing infrastructure, a shortage of locomotives, and a lack of rolling stock, PR has had the biggest difficulty throughout this time period. As a result, the number of freight trains departing ports each day has decreased from 96 to just one per day [5]. Furthermore, between 2010 and 2013, the number of terrorist attacks against PR increased dramatically [15]. As a result, PR's freight volume dropped from 7.23 million tonnes in 2007-08 to 1.01 million tonnes in 2012–13, as well as from 6187.3 to 419.3 million ton-kilometres. Since then, PR has used a number of strategies to boost rail freight transportation (for example, boosting freight trains from ports, strengthening dry ports, and so on [16]. As a result, rail freight increased dramatically in tonnes and ton-kilometres in 2016-17, reaching 5.63 tonnes and 5031 ton-kilometres, respectively. As a result, Figure 1 shows data on CO2e emissions from 1960 to 2018.

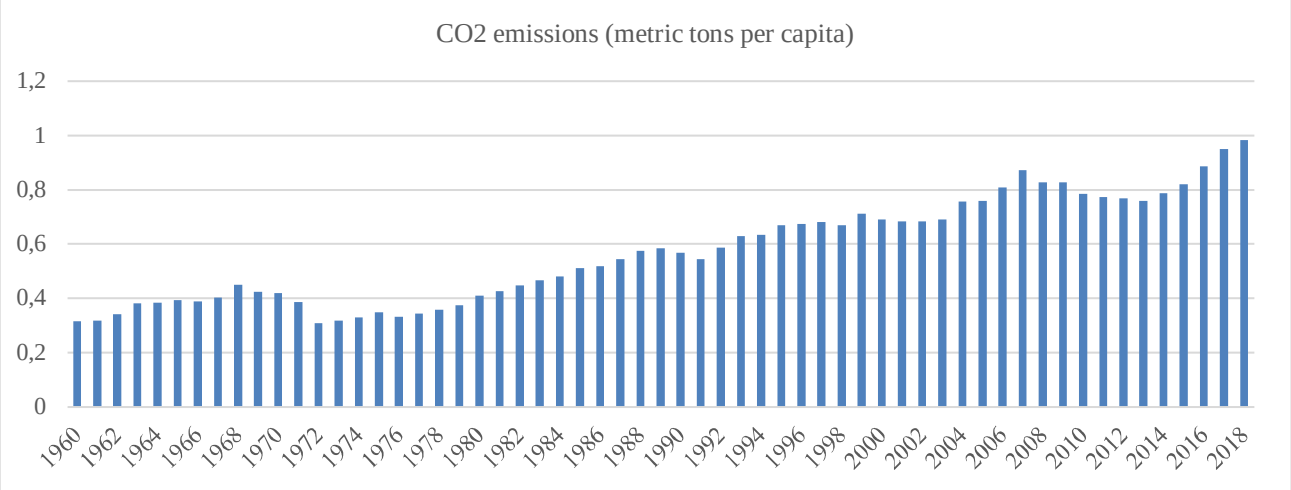

Figure 1 CO2 emissions data of Pakistan (metric tons per capita)
Source: [29]

With the increase in the demand of railway freight distribution, there has been a steady increase in reliance on fossil fuel-derived energy over the last century, resulting in increased CO2e emissions [17,18]. Transportation is deeply ingrained in all social functions, including medical logistics, raw materials, consumable products, technology products, energy sources, and a wide range of other human activities. As a result, the transportation industry is a major source of CO2e emissions [19], mainly due to growing infrastructure development and global transportation demand It also contributes to air pollution by releasing particles into the atmosphere from both stationary and mobile sources [20]. It's important to note that railway transportation is expected to expand significantly in the near future [21], All modes of transportation, including construction, maintenance services, operation, and decommissioning, must cut carbon footprints at all phases of their life cycles [22,23].

A literature review on CO2e emissions from railway maintenance finds that real activity-based monitoring and

estimation are restricted and lacking in detail, and that the results are impossible to check due to the use of broad assumptions. Because of data limitations and previously published studies, assumptions have been made about railway resurfacing machinery's fuel usage and track-processing rates. They properly proposed that more research on the technology's fuel usage and CO2e emissions be conducted in order to confirm their findings [24].

In our research, first of all, we looked at the shortest path (SP) of a rail network for passenger and freight transportation. The findings can be applied directly to the railway system. To overcome our challenge, we used an ILP model. To accomplish our objective of reducing path length, travel/transit time, and CO2e emissions, we used Q-learning and a genetic algorithm. The key distinction between our research and the investigations proposed by [25] are shown in Table 1.

Table 1 Research gaps

Research framework	[25]	Our research
Model formulation	Integer linear programming	Integer linear programming
Solution algorithm	MONET	Q-learning and genetic algorithm
Research region	Anonymous case study	Lahore-Karachi (Pakistan)
Objectives	Minimisation of path length and travel time	Minimisation of path length, travel time, and CO2e emissions

Using a multiobjective genetic algorithm, we propose the first study in Pakistan to identify the SP and provide a trade-off between cost, time, and CO2e emissions. This study helps decision-makers, policymakers, freight forwarders, importers, and exporters in Pakistan in lowering transportation costs, completing green orders, and delivering goods promptly. Second, this research will assist freight forwarders in providing clients with door-to-door delivery at the lowest possible transportation cost. The following are the research's main contributions:

1. Modelling of integer linear programming (ILP) problem for Pakistani transportation level considering the cost, time, and CO2e emissions in the SP distribution network;
2. To find the SP for railway network between two capital cities of Pakistan by applying the Q-learning algorithm;
3. To solve the multi-objective optimisation problem by creating Pareto fronts to the trade-off between path length, travel time, and CO2e emissions generated by the genetic algorithm;
4. To analyse the railway networks by applying real-world data for the multi-objective optimisation problem.

This paper has been split into five sections. Section 2 shows crucial technical information on the description of real-life problems. This section also provides details for the solution methodology of the problem and details of the assumption about the ILP transportation problem. Section 3 presents the parameters and preliminary data applied in the calculations & solution methodology. Section 4 provides results and discussion. This section also compares and proposes the multi-objective problem concerning the existing railway network. Lastly, Section 5 provides the conclusions and some additional developments and implications for studies.

1.1 Problem statement

This section provides the definition and design of the multi-objective optimisation problem of minimising travel costs, travel time, and CO2e emissions by formulating an integer linear programming problem.

1.1.1 Problem definition

In this study, we formulated our problem as a multiobjective integer linear problem, with the major and secondary functions being the minimisation of overall cost and time for cargo transfers in the nodes. In addition, the carbon emissions rate function is considered as a third goal. The primary goal of this topic is to minimise the adverse consequences of road transportation, which result in high carbon emissions and fuel consumption for logistics systems, while also meeting consumer expectations concerning transit times. In the problem, passenger and freight trains between Lahore and Karachi carry passengers and cargo simultaneously.

The suggested model takes into account network design for transportation in Pakistan; nonetheless, several assumptions for real-life scenarios are provided. For example, the proposed path is based on the existing path's work, passenger and freight trains are considered as one train due to the lack of a separate freight train, a single railway track is chosen, speed is constant for both trains, emissions factors and transit time calculations are the same.

2 Methodology

2.1 Model

One of the most efficient techniques to solving the SP problem is to use various heuristic algorithms. The standard single-source shortest path (SSSP) model is used as a foundation for developing an ILP model. Let us consider, G = (V, E) where the directed network of railway transport for the passenger is a set of V nodes, and E is a

set of arcs {(a, j) ….(m, n)} with d_ij shows the travel distance on nodes (i, j). The SP from source s to destination t is fixed by the set of arcs, which produces SP based on applied factors like the distance of arc d_ij. The formulation of the model in the form of a linear program is given below.

Notations

i, j	set of nodes $(i, j = 1, \ldots, I)$
$c_{ij}, k \in \{1,\ldots,r\}$	for each iteration $k = 1, \ldots, r$
V	finite set of nodes on a directed graph where $G = (V, E)$
E	finite set of edges on directed graph where $G = (V, E)$
s	source node $s \in V$
t	destination node where $t \in t \in V$
c_{ij}	cost on the edges as $i \in V$, and $j \in V$
t_{ij}	time on the edges as $i \in V$, and $j \in V$
$CO_{2_{ij}}$	CO2e on the edges as $i \in V$, and $j \in V$
ed_{ij}	an edge from vertex $i \in V$, and $j \in V$
S	the current state of an agent.
A	the current action selection according to the policy.
S'	the next state of the agent where it ends up.
A'	for the estimation of the Q-value, the next possible best action of the agent.
R	the current reward in response to the current action after interacting with the environment.
r	the discounting factor for future rewards with values between greater than 0 and less than or equal to 1.
α	step length for the estimation of $Q(S, A)$.

$$\text{Min } f_1 = \left(\sum_{(i,j)\in V} {c^1}_{ij} ed_{ij}, \ldots, \sum_{(i,j)\in V} {c^r}_{ij} ed_{ij} \right) \quad (1)$$

$$\text{Min } f_2 = \left(\sum_{(i,j)\in V} {t^1}_{ij} ed_{ij}, \ldots, \sum_{(i,j)\in V} {t^r}_{ij} ed_{ij} \right) \quad (2)$$

$$\text{Min } f_3 = \left(\sum_{(i,j)\in V} {CO_2}^1{}_{ij} ed_{ij}, \ldots, \sum_{(i,j)\in V} {CO_2}^r{}_{ij} ed_{ij} \right) \quad (3)$$

s.t.

$$\sum_{j\in V} ed_{sj} - \sum_{j\in V} ed_{js} = 1 \quad (4)$$

$$\sum_{j\in V} ed_{tj} - \sum_{j\in V} ed_{jt} = -1 \quad (5)$$

$$\sum_{j\in V} ed_{ij} - \sum_{j\in V} ed_{ji} = 0 \quad \forall i \in V\{s,t\} \quad (6)$$

$$\sum_{(i,j)\in V} {c^1}_{ij} \leq C \quad (7)$$

$$\sum_{(i,j)\in V} {t^1}_{ij} \leq T \quad (8)$$

$$\sum_{(i,j)\in V} {CO_2}^1{}_{ij} \leq CO_2 \quad (9)$$

$$ed_{ij} \in \{0,1\} \qquad \forall (i,j) \in E \quad (10)$$

Equation (1) shows the minimisation of the total path length of the railway network from the source node s to the destination node t. Equation (2) depicts the minimisation of the total travel time in the railway network. Equation (3) defines the minimisation of the CO2e emissions in the railway network. Equation (4) shows one edge that should

be leaving the node s, which must not be on the cycle. Equation (5) indicates that one edge must be entering the node t, which should not be on the cycle. Equation (6) ensures the conservation of the flow of the constraints. Equation (7) shows that the cost of each arc should not be exceeded by the total cost in the SP network. Equation (8) indicates that the time of each arc should not be exceeded by the total cost in the SP network. Equation (9) presents that the CO2e of each arc should not be exceeded by the total cost in the SP network.

2.2 Solution methodology

We used two different solution algorithms in this investigation. The first is the Q-learning algorithm proposed by [26]. Secondly, we generated Pareto front solutions generated by genetic algorithm [27] to trade-off cost, transit time, and CO2e emissions. Figure 2 shows the selected nodes in the railway network for the SP problem (source node: 0; destination: 30).

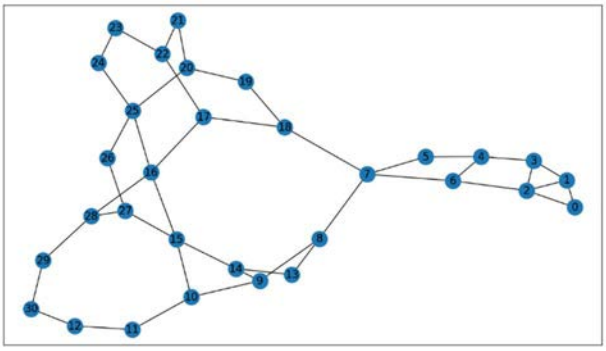

Figure 2 Selected nodes in the railway network for the SP problem (source node: 0; destination: 30)

2.3 Reinforcement learning

Reinforcement learning is a simplified model of the learning process in which a learning agent continuously interacts with its environment and learns to produce the best solution over time. The learning agent meets a range of scenarios in its surroundings throughout the learning phases. State refers to all of the situations that an agent encounter. During each stage, the agent chooses from a list of authorised activities, earning variable rewards and punishments. In whatever state, the agent is rewarded the most for optimal behaviour. Figure 3 depicts the reinforcement learning process and the agent's interaction with the environment.

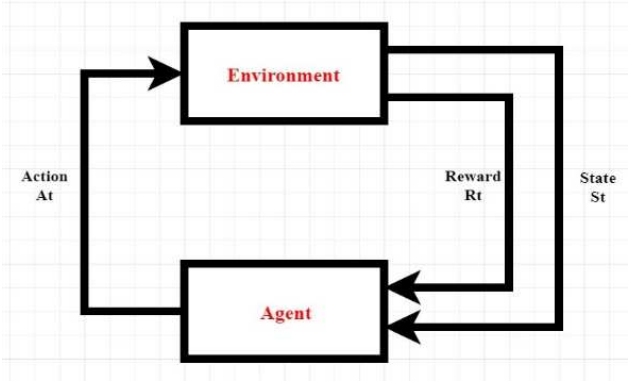

Figure 3 Deep reinforcement learning

Q-learning is a fundamental form of reinforcement learning which uses Q-values to improve the behaviour of the learning agent. We define the value of Q for actions A and states' S. Q(S, A) provides the estimation of taking action A at various states S and this estimation is iteratively calculated by following the temporal difference update rule.

An agent progresses through different states S in the course of its actions, starting from the starting state and progressing to the subsequent states based on its actions and interactions with the environment. As indicated in Table 2, at each state or transition, an agent performs action A, receives a reward or punishment from the environment, and advances to the next state. This process is finished when the episode is completed and no additional transitions are feasible. The temporal difference rule can be represented as follows:

$$Q(S,A) \leftarrow Q(S,A) + \alpha\big(R + rQ(S',A') - Q(S,A)\big) \quad (11)$$

When the agent interacts with the environment, the update rule of estimating the Q-value is applied.

Q-learning algorithm pseudocode

begin
Initialisation:
$Q_{m*n}(s_t, a_t) \leftarrow \{0\}$, (n states and m actions)
for (each episode):
Set $s_t \leftarrow$ a random state from the states set S;
while ($s_t \neq$ Goal state)
Choose at in s_t by using an adequate policy ∈-greedy, etc.);
Act at, and receive reward/penalty and s_t+1;
Update $Q(s_t, a_t)$ using equation 11
$s_t \leftarrow s_t + 1$;
end-while
end for
end

Table 2 Reward matrix

(12, 11) (0, 1) (1, 0) (1, 3) (3, 1) (3, 4) (4, 3) (4, 5) (5, 4) (13, 14) (14, 13) (14, 15) (8, 13) (15, 14) (9, 14) (5, 7) (15, 16) (16, 15) (15, 10) (16, 17) (17, 16) (17, 18) (7, 18) (18, 19) (19, 20) (20, 19) (20, 21) (21, 20) (21, 22) (22, 21) (22, 23) (23, 22) (23, 24) (24, 23) (24, 25) (25, 24) (16, 25) (17, 22) (25, 26) (26, 25) (25, 20) (26, 27) (27, 26) (27, 15) (28, 16) (27, 28) (28, 27) (28, 29) (29, 28) (29, 30) (30, 29) (30, 12) (12, 30)
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2.4 Genetic algorithm

GA leverages the premise of the presence of the fittest cross-breeding population to construct a robust search strategy. To that goal, the solutions with a finite population that are based on the defined problem are first kept. Second, from current populations, new populations are generated by prioritising solutions and rating them based on their fitness values, followed by cross-breeding of the fittest to produce the best-optimised offspring. The GA algorithm operates solely on the fitness value and has no other knowledge. Generations generate solutions, and weaker ones are weeded out since they have no progeny. The stronger solutions, on the other hand, remain and mix parental qualities to form new families, and the cycle repeats. In this work, the generated mathematical model with GA application is written as M-files in MATLAB software.

- The evaluation of the target population as a whole.
- Best and fittest parents chosen from a population.
- Creating a new generation by combining the children of two parents.
- New generation mutation.
- If the operation doesn't end, go back to the best-found individual in the current population.

Multi-objective genetic algorithm pseudocode

Begin
$t = 0$
Initialise the chromosome population $P(g)$;
Calculation of initial population fitness $P(g)$;
While not termination criteria do
$g := g + 1$;
Select $P(g + 1)$ from $P(g)$;
Crossover $P(g + 1)$;
Mutate $P(g + 1)$;
Evaluate $P(g + 1)$;
End While
Result output to an external archive
End

2.5 Computational experiments

This part explains the original data utilised for the model, as well as a basic summary of the real-world cases

and their relevance to this research. A few design and operation assumptions for railway networks are also mentioned.

We used data from Google Maps and Railway Pakistan for location, distances, links between cities, vehicle capacity, transfer time, fuel consumption, and the total number of nodes in this analysis. Existing rail movements are also taken into account in our research. We assumed that the rail speed is constant. CO2e emissions are calculated based on the same parameters and emission factors proposed by [28]. The railway emission factor is derived using the average rail fuel consumption (litres diesel/revenue ton-kilometre) from the Railway Association of Canada's locomotive emissions monitoring programme in 2015. The emission factor used to calculate CO2e emissions in our study's existing and planned shortest rail path is 15.2g CO2e emissions/ton-km. Figure 4 shows the existing railway path between Lahore, Punjab and Karachi, Sindh. Figure 5 shows the proposed path of railways.

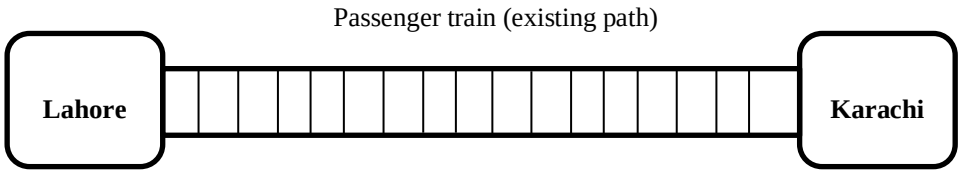

Figure 4 Existing railway path between Lahore, Punjab and Karachi, Sindh

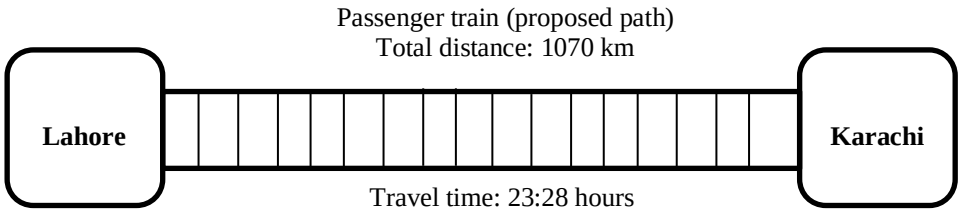

Figure 5 Proposed rail track for SP

3 Results and discussion

We examined our ILP model in different cases in this section. The focal differences between the cases are the cost of the path, travel time, and CO2e emissions in the railway network from Lahore to Karachi. We obtained the SP first by using Q-learning. Secondly, we applied a genetic algorithm and compared the results of our problem. The ILP model is performed on a system with Intel Core I5 2520 M CPU with a 2.50 GHz dual-core processor and 4.00 GB of RAM. Figure 6 shows the propsed shortest path generated by Q-learning algorithm.

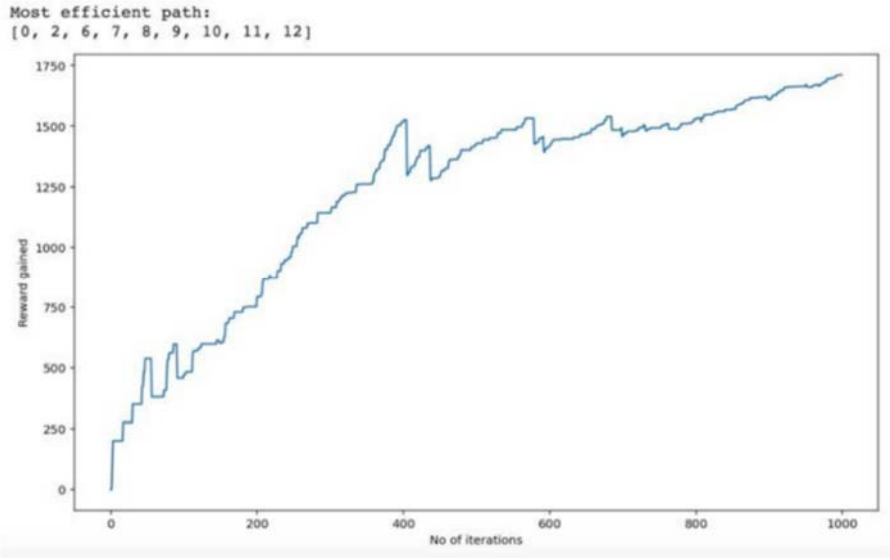

Figure 6 The proposed SP from Lahore to Karachi using RL

3.1 Case 1 - existing rail track

In this case, the operation begins at 6:45 a.m. at the Lahore railway station (LRS) and ends at 5:00 a.m. at the Karachi railway station (KRS), traversing a total distance of 1214 kilometres and stopping at 46 nodes. The train has a daily capacity of 1000 passengers, with 12 AC and 14 economy class coaches. The passenger/freight train (Fareed express) travels from LRS to KRS in 26 hours and 45 minutes. For the calculation of CO2e emission, we used the railway emission factor proposed by [28]. Based on path length (existing track and proposed track developed by Q-learning) and constant weight carried by train, the CO2e calculations are done. The method covers the following aspects:

Cargo features: container count or goods weight.

Route features: CO2e emissions per tonne-kilometre.

According to this emission factor, the total CO2e emissions from this method are 18.45 kgs-CO2e emissions/ton-km, where one km-ton emission equals 15.2 g CO2e emissions. Table 3 also shows the overall length of the existing passenger rail route.

Table 3 Selected nodes and distances to find the shortest path

Shortest path train	Nodes	Distance
Lahore	0	0
Sharqpur	1	27
Raiwind	2	38
Haripur	3	119
Chunian	4	87
Kamalia	5	216
Hujra Shah	6	126
Jampur	7	481
Sahiwal	8	170
Ghotki	9	692
Rohri	10	749
Khanpur	11	380
Kot Samba	13	81
Tranda	14	483
Rahim Yar Khan	15	587
Goth Jooro	16	506
Sadikabad	17	606
Mirpur Mathelo	18	683
Ghotki	19	692
Rohri	20	749
Mahrabpur	21	833
Bhiria Road	22	867
Padidan	23	874
Nawabshah	24	933
Shahdadpur	25	980
Tando Adam	26	1022
Hyderabad	27	1044
Kotri	28	1066
Landhi	29	1201
Drigh Road	30	1199
Karachi Cantt	12	1208

3.2 Case 2 - proposed SP

Figure 5 shows the graphical illustration of the proposed shortest path. In this operation, we propose the shortest railway course from Lahore (Punjab) to Sindh to reduce travel costs, time, and CO2e emissions. Our activity begins at 6:45 a.m. at LRS and concludes at 3:28 a.m. at Karachi Railway Station. For existing and projected routes, we used the same criteria (capacity of train, speed, type of fuel, starting time, CO2e emission factor). The whole length of the passenger train's chosen route is shown in Table 3. The findings of the Q-learning algorithm suggest that the total distance of the railway track is 1070 km, as shown in Figure 6, which illustrates the proposed shortest path. Total time and CO2e emissions are 23 hours 28 minutes and 16.18 kgs CO2e/ton, respectively.

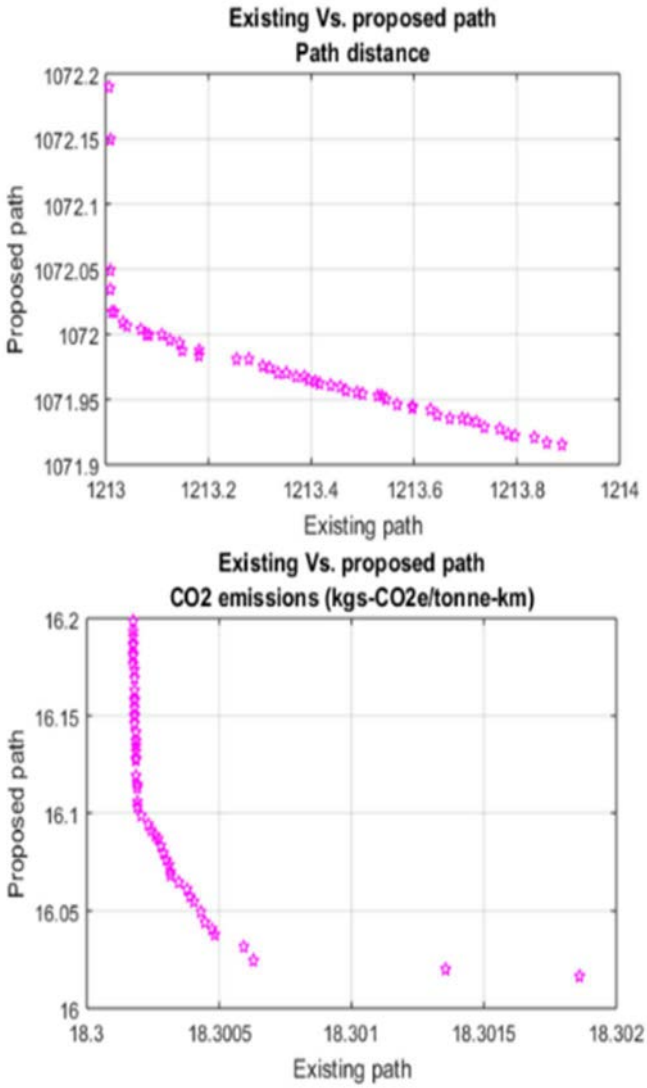

Figure 7 Existing and proposed path distance and CO2e emissions in rail network

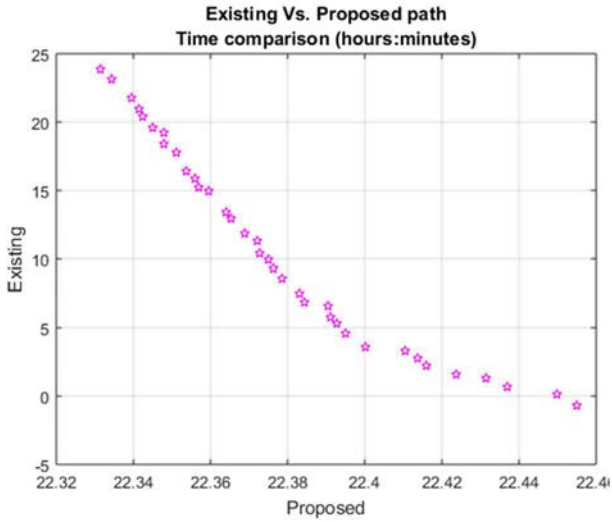

Figure 8 Existing and proposed total travel time in the rail network

The total path lengths and CO2e emissions in existing and prospective rail tracks between the Punjab and Sindh provinces are depicted in Figure 7. Figure 8 depicts the total travel time comparison between current and proposed rail routes, while Figure 9 depicts the savings in terms of travel time, path length, and CO2e emissions by comparing existing and proposed railway pathways. Our analysis shows that the proposed railway network is better than the existing railway network.

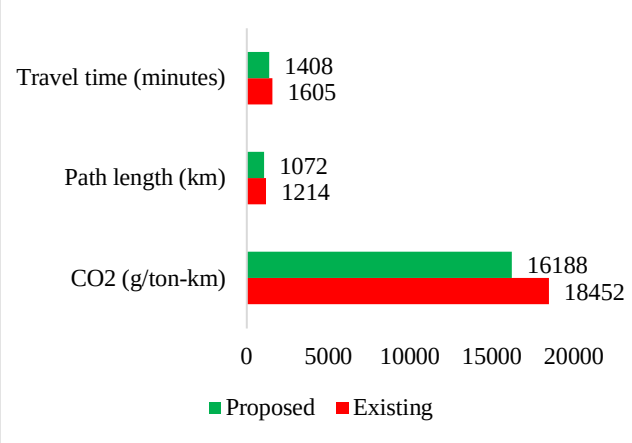

Figure 9 Savings in total time, path length, and CO2e emissions

4 Conclusion

To formulate the problem, we employed integer linear programming. In this study, we used two algorithms: Q-learning and genetic algorithms. We employed reinforcement learning, specifically a Q-learning method. We used Pakistan's railway network to find the quickest path to execute the Q-algorithm.

- First, we calculated the SP between Pakistan's Punjab and Sindh provinces and created Pareto front solutions by applying multi-objective optimisation to the SP and existing path data.
- The Pareto front solutions presented help decision-makers and practitioners arrange their transportation more strategically.
- The results of multi-objective optimisation indicate that adopting the proposed SP to Pakistan's railway network would result in savings of 13% in path length, total travel time, and CO2e emissions.
- Furthermore, the scope of this study could be broadened by investigating multi-modal shortest path for passenger and freight movements in Pakistani transportation and logistics operations.

Conflict of interest

The author of this paper declare that he has no financial or personal ties that could have influenced their work, and they have nothing to hide.

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QUALITY CONCEPTS IN PRODUCT DESIGN – SURVEY

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Keywords: quality concepts, survey questionnaire, QFD, SQC, prototyping.
Abstract: Without quality, nothing can be accomplished in the current competitive world. Quality is one of the fundamental features in product design concepts. By building the design based on the concept idea, product design concepts enable the exploration of several ideas. The following factors, which are given below: 1. Beauty or outlook 2. Cost; 3. Performance 4. Guarantee and warranty 5. Life expectancy the degree of product design may be evaluated using a variety of quality management technologies, such as Quality Function Deployment (QFD), Six Sigma, and Statistical Quality Control Techniques. With the use of modelling software applications, prototyping and testing is a technique to confirm the quality of product design. Consumers will only purchase high-quality products, according to the literature. By structuring the survey questionnaire, a detailed survey on the fundamental characteristics of product design concepts has been attempted in this work. Employees of various organizations and students at higher education institutions and technical institutes are the respondents taken into account in this work.

1 Introduction

The foundation for CAD is the methodical and well-thought-out process of product design (Computer Aided Design). Product design is the process of sketching ideas to produce a 3D model as a prototype to present the full concept using modelling software. To optimize flexibility and provide effective part design that meets criteria, CAD drawings can be created. By using best practices, quality principles in product design encourage additional innovation. From the beginning of the development process, creating a sustainable product design ecosystem is not an easy undertaking. A key success factor in company nowadays is quality.

The quality of product design concepts vary greatly from one situation to another. Deming asserts that a product's fundamental qualities determine the standards and expectations for its service. Customer-focused quality meets the demands and expectations of the customer. The definition of new product development is a process to create, test, and guarantee the profitability of new products.

Academic have focused their attention on the topic of "Design Theory and Methodology," which has produced a sizable amount of findings.

One of the most difficult and creative aspects in the product design process is coming up with an initial shape design for unique product concepts. By giving the product designer with additional data from multiple corporate departments and a tool that enables the designer to explicitly declare the design objective of its design concept at a very early stage of geometric shape development, the technique attempts to help the designer.

In order to preserve their place in the market, it is only natural for all firms to be competitive. Maintaining consumer satisfaction with their products is the only strategy businesses have in a market that is very competitive.

Small and medium-sized enterprises struggle to manufacture high-quality goods within their limited financial and time restrictions due to a lack of staff and other resources. They have the opportunity to enhance their products as crowd sourcing becomes more popular by harnessing the knowledge of a large set of audiences, including their potential customers. High-quality products will help businesses stay competitive on a worldwide scale by improving user experience, delivering greater social and environmental benefits to our society, and satisfying the needs of manufacturing enterprises and varied users throughout the product life cycle.

Perceived quality is one of the crucial elements in product development that establishes a successful design. This study proposes a novel approach for doing so from the viewpoint of engineering by breaking perceived quality assessment into its component elements and developing a structure from the level of fundamental (or "ground") qualities. From this angle, it encompasses almost all facets of perceived quality. The study provides a novel method for evaluating the relative importance of perceived quality characteristics, resulting in a fair assessment of the finished product's quality under the given conditions. The suggested approach helps to reach the equilibrium of the product's quality equation while taking design work, time, and cost estimates into account. The Perceived Quality Framework (PQF), a taxonomy of perceived quality qualities, is presented by the authors.

Businesses develop new products to preserve their competitiveness and expand their market share. Thus, new product development, in the opinion of Kahraman et al., is an essential activity and crucial technique to retain competitiveness in the context of fierce competition.

Pricing and sales competitiveness should be taken into account while developing a future corporate strategy.

nonetheless, to secure the long-term growth of the company.

The necessity for a product, which is determined by market and consumer demands, serves as the foundation for manufacturing. From the conception of the idea to the finished product, there are two main steps. Companies today face enormous pressure to develop and provide new products more quickly while keeping their prices low. To meet these business imperatives, businesses must manage a number of important difficulties related to product conception.

Design is at the core of every invention. Product design does not include employing design and development software or making things look nice.

The main goal of product quality control is to strike a balance between price and product quality. Product quality is a general phrase that can be evaluated from a variety of perspectives. Furthermore, quality control throughout production and actions that happen after a product is completed are frequently given too much attention in the literature that is now available. For instance, Anastasia shows how quality control of product quality is handled through production, controlling warranty costs through fault detection and maintenance, and minimizing the importance of product design quality. The following picture displays the many stages of the lifecycle management of product quality as indicated in figure 1.

Product service systems (PS2 or PSS) are often combined with the product to provide services connected to the product, such as maintainability, repair, update, and quality warranty over the whole life cycle, in order to better satisfy user requirements. In this case, a standalone product is not sufficient to meet client needs. As a result, we sum up maintainability, design quality, manufacturing quality, and recycling when defining product quality. As a result, we think that a product's life cycle has four stages: design, manufacture, maintenance, and recycling. The relationship between these notions is seen in Figure 2.

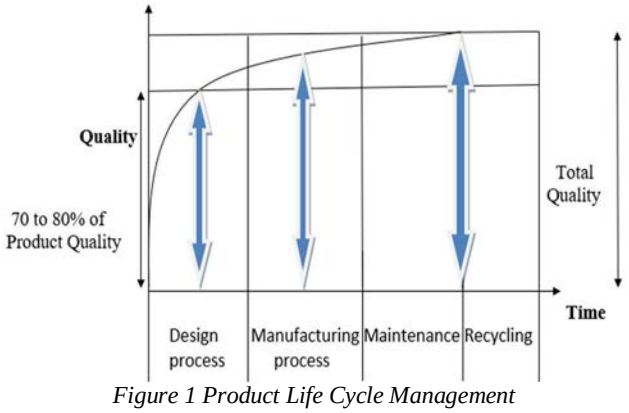

Figure 1 Product Life Cycle Management

Figure 2 The connections between quality-related variables across the course of a product's life cycle

The manufacturing industry has conducted a large number of studies to ensure the quality of the finished product from a variety of perspectives, including manufacturing methods and modelling approaches, the influence of human factors, and crucial technologies of intelligent design for customized products. There are two categories of significant variables that influence manufacturing quality: hard and soft factors. After-sale services, such as maintenance and recycling, are crucial to the successful marketing of many products since they enable customers to get the most out of the products.

After-sale services are designed to assist consumers with problems including product failure restoration and usage concerns that, if not effectively addressed, could result in dissatisfaction. In light of the expanding significance of after-sale service, Rolstadaas et al. investigated a number of after-sale service-related themes, including company strategy, service-delivery methodology, performance measurements, service portfolio, and product planning and control. According to Markeset et al., cost consideration, technological consideration, human considerations, statutory requirements, accidents, and other factors are the key factors affecting maintainability. Takeuchi and Quelch provided a list of the practices used to guarantee the caliber of the after-sale services. The manner in which items are collected, local government resources, pricing practices, financial support, and geographic location are all regarded to have an impact on the quality of recyclables.

Although design for manufacturing, design for assembly, and design for disassembly are recommended as design guidelines, comparatively fewer studies have been done on how to integrate product design quality into product after-service qualities at the maintenance and recycling stages than on manufacturing.

We are dealing with a complicated, multilayered adaptive system where a person is the primary agent when we talk about perceived quality. Reaching the best perceived quality level within the constraints of available technologies, development time, production system capabilities, and financial constraints is the truly difficult task. A lot of businesses employ high-quality products as a competitive advantage and a way to boost performance (Reed, Lemak, & Mero, 2000). In terms of financial metrics and stock market valuation, companies that have received quality awards typically perform better than other

companies (Hendricks & Singhal, 1997). The only way to deal with this uncertainty is to build a long-term relationship with clients, as customers may have second thoughts after completing a purchase (Flynn, Belzowski & Haas, 2002).

An internal design team made up of individuals with varied design expertise commonly completes product design tasks in traditional design contexts. Because they lack the qualified staff and auxiliary resources to support their product design processes, small and medium-sized firms (SMEs) cannot benefit from this type of design collaboration method. Small and medium-sized businesses (SMEs) have demonstrated a high interest in using platforms based on crowd sourcing to carry out product design chores or improve their products because of the benefits of crowd sourcing, such as its low cost and widespread participation of crowds. The holes created by SMEs' lack of employees and other resources may be filled via crowdsourcing.

Quality control practices have been demonstrated to enhance organizational performance for both product and service businesses (Powell, 1995). In research done in 2001 by Lars, Michael, and Anders, 482 Swedish businesses were split into organizations focused on products and those focused on services. Euphemia and Sian are researching how the retail service quality dimension and the product quality dimension affect customer loyalty in Hong Kong (2010).

Quality techniques have been demonstrated to enhance organizational performance in both product and service organizations (Powell, 1995). Lars, Michael, and Anders (2001) investigated the distinctions between key internal quality practices for product versus service organizations using data from 482 Swedish businesses. Euphemia and Sian examined how factors affecting consumer loyalty in Hong Kong in their 2010 study.

2 Literature review

The following section illustrates the detailed review of literature on importance of quality concepts in product design applications. The following survey has broadly categorized into two levels such as National and International levels as discussed here (Figure 3).

Figure 3 Classification of Quality levels

2.1 Classification of Product Quality concepts in design based on National level

2.1.1 Literature works on Quality concepts in Product Design Using Quality Function Deployment

M. MuthuKumaran et al. [2016] The deployment of quality functions is reviewed in the literature in this essay (QFD). The introduction and background of the QFD survey are discussed first, then the methodology for deploying the quality function. Then, a categorical analysis of the functional fields, applicable industries, and methodological development of QFD is carried out. It is hoped that by providing a concise overview of QFD in this work, academics and practitioners will be able to more easily access the relevant QFD studies and applications, which will encourage further advancement in quality deployment.

P. Sivasankaran [2021] By analyzing several studies from renowned journals, this essay investigates the importance of quality concepts in product development. In order to improve the quality of product design, the tool QFD (Quality Function Deployment) is used to analyze the various aspects of product design, including cost, service life, maintenance, and visual appeal. Analysis is carried out in QFD to enhance the calibre of the product design in accordance with the customer's evaluation. QFD assists the product development management team in making decisions on the product quality by analyzing and enhancing its qualities. A cross-functional team made up of members from design, safety, quality, and maintenance will be present in every company. With the help of the cross-functional team member's suggestions, it will be possible to improve the product's usefulness, design, and safety.

Amit Adhaye [2013] This article has looked at the efficiency of the customer-focused quality engineering technique known as "Quality Function Deployment (QFD)". Given the extensive evaluation of QFD and its potential areas for development, the possibility of more research may emerge. It has been found that QFD is the most extensively used method for analyzing customer satisfaction and quality design. This study's objective is to synthesize the methodology and the benefits of adopting QFD by reviewing a number of research studies.

Ravi Kumar Singh et al [2018] In order to determine whether Quality Function Deployment (QFD) may be utilized to alter customer expectations in favor of design quality, this study will look into this possibility. This goal entails identifying the requirements of the consumer and the details of the product through direct interviews, observation, and data analytics. Utilizing a precise ratio-scale priority, the hierarchy diagram is utilized to quantify and rank client desires. Prior to converting the requirements into quality attributes, customer needs were first classified and given a priority ranking. Utilizing quality function deployment, product design specifications are created using the acknowledged quality qualities

(QFD). In this study, the automobile industry is implemented using the QFD technique, which is employed in a variety of industries. The connection between the product and the client's requirements

Eshan S. Jaiswal [2012] Quality Function Deployment (QFD) was first developed in Japan in the late 1960s and adopted to North America and Europe in 1983. In this article, a quick overview of the QFD process and methodology for product development will be provided. After becoming familiar with the tool, a case study that applies the method to actual situations will be presented. The case study will show how the QFD approach was applied to create a new tape product and provide guidance to others who may want to utilise it. A process called Quality Function Deployment (QFD) "transforms user needs into design quality, deploys functions creating quality, and deploys methods for achieving the design quality into subsystems and component parts, and eventually to specific elements of the design."

S. A. Puviyarasu [2016] The main objective of this study is to use the concept of quality function deployment methodologies to enhance the existing offered product. A method for developing designs with high levels of customer satisfaction that redesign products to satisfy consumer demand is called the quality function deployment (QFD). It's also a methodical or planned strategy to make sure that the customer's opinion is taken into account when developing a procedure, good, or service. This study focuses on understanding the QFD idea and applying it to redesigns that satisfy customer needs.

2.1.2 Implementation of House of Quality in product design concepts

Praveen Shrivastava [2013] The House of Quality (HOQ) is one of the matrices used in the iterative process known as Quality Function Deployment (QFD). It is the driving force behind the entire QFD process. The House of Quality Matrix is the most well-known and frequently used tool for new product design. It transforms customer requirements into the appropriate number of technical goals that must be attained by a new product design utilizing benchmarking data and marketing research. A multidisciplinary team, including members from the most crucial divisions of the business, such as manufacturing engineering, design engineering, and marketing, is in charge of carrying it out. Automobile, electronics, integrated circuits, and apartment manufacturers like Toyota, Ford, GM, Hewlett-Packard, AT&T, ITT, and others have all made significant investments.

A.S. Khangura and S. K. Gandhi [2012] In a time of intense competition, it is crucial to implement the established quality system at all levels of the organization and to achieve the highest possible quality standards at all levels. These quality improvements are based on customer input concerning new and existing products in the market as well as benchmarking data from rival companies. A high-quality, inexpensive product that better meets consumer wants is to be designed using a systematic process, which will also increase the product's competitiveness. The majority of businesses have changed in response to product development. A quality tool called Quality Function Deployment (QFD) aids in translating customer feedback into new goods that precisely meet their needs.

Peetam Kumar Dehariya et al [2015] In the paper, a logical and useful approach to Green Quality Function Deployment (GQFD), a quality management system with routine product development improvement based on customer-focused survey data, is discussed. GQFD serves as an example of how to balance product development with environmental preservation. GQFD is not applied to determine their properties and levels. GQFD records what product designers "think" will best satisfy customer needs while taking environmental considerations into mind. The use of an air conditioner served as a case study for the application of GQFD in this study. When constructing a new air conditioner, use GQFD to identify the parameters and functions that are most important to the client before deciding on the technical specifications. These critical requirements are subsequently submitted to the quality control division, where a relationship is established.

2.2 Classification of Product Quality concepts in design based on international level

2.2.1 Literature works on Quality concepts in Product Design Using Quality Function Deployment

Chenggang Yin et al [2019] Investors must first identify the appropriate market opportunities early in the firm strategy in order to support subsequent technical efforts in the product design and development (PD&D) process. A variety of processes are included in the product design and development (PD&D) process, such as business strategy, concept generation, detail design, prototype & test, production, after-sale support, etc. In the Background section of this article, processes for product design and development (PD&D) and survey technique were introduced. With the aim of developing non-destructive testing robots utilised for on-site inspection of wind turbine blade flaws, this study provided a case study product development project. 34 second-year undergraduate students who were involved in the case study project responded to the survey and questionnaire that the author had developed.

Dara Schniederjans and Marc Schniederjans [2015] Due to the escalating competition in the market, organizations seek for greater innovation in their products and services. Quality management has the power to reenergize an organization's product, process, and administrative innovation when properly matched with internal circumstances. This essay will address the relationship between social and technical quality management and innovation. Additionally, this study undertakes an empirical analysis of confounding factors

including task difficulty, organizational size, and managerial ethics that influence the relationship between quality management and innovation. Based on an empirical analysis, we discover that social quality management practices—not technical quality management practices—are positively related to creativity. We also find that technical and social quality management have a beneficial reciprocal relationship. Furthermore, our research reveals a connection between quality management and innovation.

Olga A. Shvetsova et al. [2021] Business-to-business (B2B) firms must choose new product concepts carefully because it will greatly affect the eventual success and reputation of the product in terms of quality and functionality. Determining the best mathematical strategy for choosing a new product's design concept in the face of fierce competition and resource limitations is the research challenge. In order to increase the effectiveness of design product decisions, this study's main objective is to present an integrated analytical strategy that integrates data envelopment analysis (DEA), analytic hierarchy process (AHP), and quality function deployment (QFD). The suggested approach uses mathematical methods to carefully evaluate and strategically select the best new product concept while taking into account the characteristics of the B2B product.

Rosnani Ginting et al. [2022] Quality Function Deployment is a method for producing goods with the needs of the consumer in mind (QFD). The QFD planning process aids in the correct implementation of various technical support solutions, which helps the business prioritize each issue. The QFD House of Quality (HOQ) tool is used to set design criteria, illustrate the relationship between respondent needs and the matrix to address those needs, and highlight the design team's attention on producing high-quality products. In order to review the QFD literature and provide background information on the history of the QFD method's development and its application to product design and development, the study will use sources that have been compiled. Planning for process quality is a key tactic for regulating product quality during the product development process.

Marvin E. Gonzalez et al. [2003] The design of school furniture in underdeveloped countries is examined using a quality function (QFD) analysis using Costa Rica as the baseline. The dynamic hierarchy process model for QFD helped the product development team achieve client expectations while working within the limitations of scarce resources. The total quality management (TQM) solution for school furniture was developed using a number of TQM technologies. A flexible, cross-functional team structure was used to complete it. A simple type of quality function deployment was used to define the intended product design, safety attributes, and service features.

2.2.2 Implementation of House of Quality in Product Design concepts

XiaolongLi et al. [2014] To improve customer happiness in creative product design, a topological structure of consumer criteria is constructed, and a novel product approach is recommended. Designers have enough guidance from the topological framework to adequately document customer wants. Analysis of the importance of client requirements is done using the analytical hierarchy process (AHP). Quality function deployment (QFD) is used to convert client requirements into requests for product and process design in order to identify the technical requirements that need rapid improvement. The product is produced in a way that is more customer-focused in this way. The TRIZ principle of creative problem solving can help designers come up with original solutions. A case study of a vehicle steering system is offered to clarify the application.

Aimin Zhou et al. [2022] Traditional product form design study frequently begins with a single factor, such as aesthetics, ergonomics, or Kansei engineering, and lacks a thorough analysis of numerous restrictions. A product form optimization design strategy focused on aesthetics and ergonomics is suggested as a solution to this issue. First, a quantitative product form aesthetic index system is constructed based on the notion of computational aesthetics. the thorough evaluation of product form aesthetics using the entropy method. By calculating the difference between the standard values and the actual values of the design parameters, the ergonomic evaluation is conducted. The Nash equilibrium is then solved to achieve product form optimization using the aesthetic and ergonomic evaluation as game players in a non cooperative game model.

Chetan Mehta & Benwang [2001] GQFD-II (Green Quality Function Deployment II) is a state-of-the-art procedure for making environmentally conscious products. However, a number of problems with the GQFD-II make it difficult to utilise. Because the LCA (Life Cycle Analysis) is complex and time-consuming, GQFD-II designers must possess a solid foundation in environmental science. Furthermore, GQFD-II product comparisons are based on a complex decision-making algorithm without a reliable quantitative base. These shortcomings are what motivated the creation of GQFD-III. The Green House in this study incorporates a Life Cycle Impact Assessment methodology, and the AHP is used to select the optimal product design (Analytical Hierarchy Process).

2.2.3 Summary of literature

Detailed survey on quality concepts in product design has been conducted by considering various tools like Quality Function Deployment and House of Quality concepts. Survey was conducted both national and International level as discussed above.

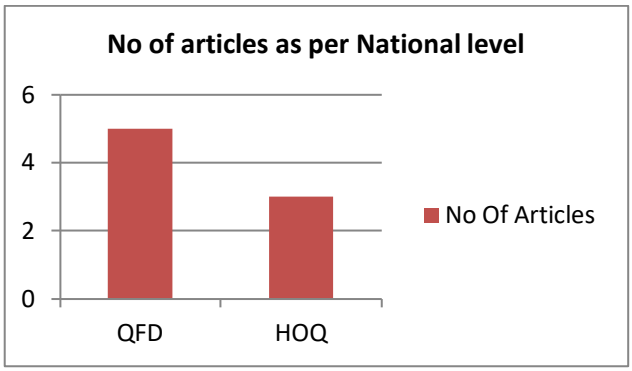

Figure 4 Number of articles categorized as per National Level

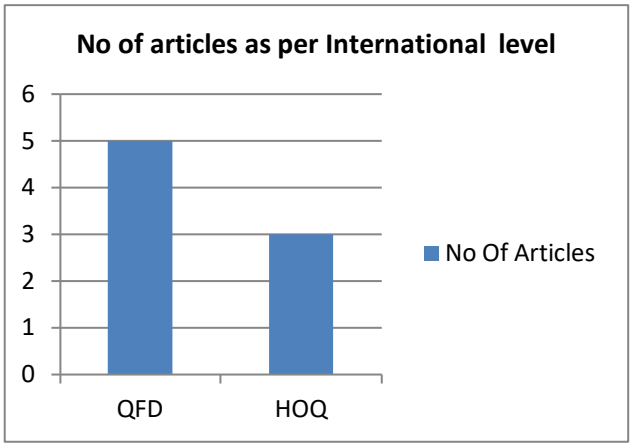

Figure 5 Number of articles categorized as per International Level

Using methods like Quality Function Deployment (QFD), the House of Quality, and the Analytical Hierarchy Process, the articles in Figures 4 and 5 describe quality principles in product design at both the national and international levels.

3 Methodology

In this section brief survey was conducted from different respondents say students, Employees and other peer groups. The following are the factors framed in questionnaire using Google forms as illustrated below.

1. Name of the Employee
2. Contact address (Preferably mail)
3. Respondent sense of perception in terms of questions.

These are the above information much useful for analyzing the quality perception in product design.

The format of questionnaire was listed as given below:

Q1. Express your Opinion about the design quality of product.

a. Aesthetics
b. Cost
c. Performance
d. Reliability
e. None

Q2. How will you measure the potential use of product?

a. Increased Performance
b. Long Service Time
c. Good Maintenance
d. None

Q3. What are the ways to validate the efficiency of product Design?

a. Quality Function Deployment
b. Statistical Quality Control
c. Quality Control
d. None

These are the above pattern of questionnaire was developed and circulated to various respondents nearly 14 respondents have given their perceptional view on quality aspects in product design.

4 Results and discussion

Based on the statistical results shown in figures 6, 7, 8 it was observed that 72.09% of the respondents given preference to performance characteristics of product , 50% of the respondents given preference to long service time and good maintenance and 62.9% of the respondents given preference to quality control techniques to validate the efficiency of product design.

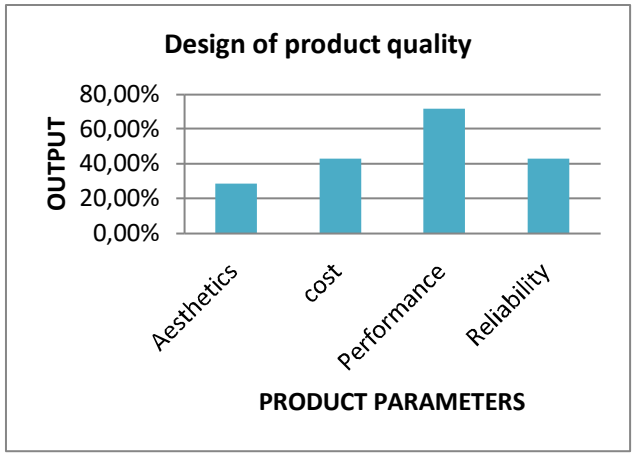

Figure 6 Design parameters of product quality

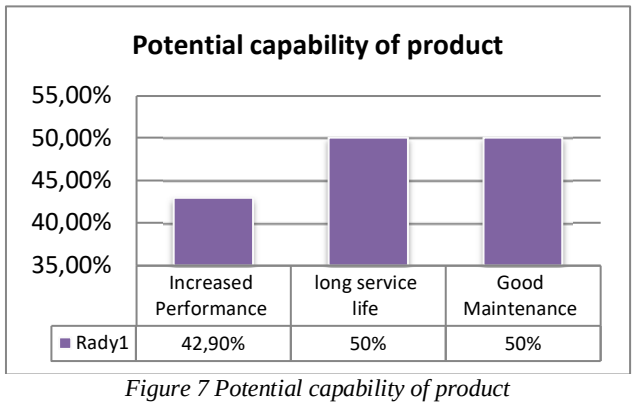

Figure 7 Potential capability of product

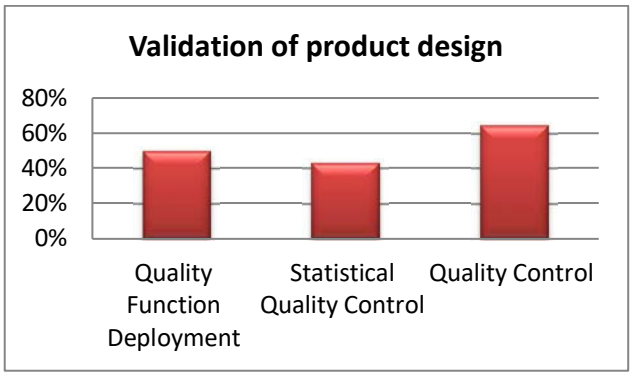

Figure 8 Validation of product design efficiency

5 Conclusion

In the current climate, nothing can be accomplished without quality because it is deeply ingrained in nature. By raising the bar for performance and quality, such as cost, dependability, and maintenance requirements, quality raises the bar for product design excellence. An effort has been made in this study to conduct a survey on several product design quality attributes. The survey's findings make it abundantly evident that a product's design quality is dependent on maintenance and safety.

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MODELS OF IMPROVING EMPLOYEE PERFORMANCE AND JOB SATISFACTION IN PT. PERKEBUNAN NUSANTARA III
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MODELS OF IMPROVING EMPLOYEE PERFORMANCE AND JOB SATISFACTION IN PT. PERKEBUNAN NUSANTARA III

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Keywords: creativity, transformational leadership, employee, satisfaction.
Abstract: Having superior employees is the hope of every company leader. The superiority of human resources can be seen from the maximum performance of employees. Employee performance problems in state-owned companies such as PT. Nusantara III Plantation in Indonesia continues to be studied on an ongoing basis. The main focus of this research is to find a model of employee performance and job satisfaction that is influenced by creativity and transformational leadership. Data collection by distributing questionnaires to 230 employees at PT. Perkebunan Nusantara III. The findings of the researchers found that an employee's creativity and transformational leadership are directly integrated with job satisfaction and employee performance. Through job satisfaction, an employee is able to give his best in carrying out his duties and responsibilities.

1 Introduction

Company transformation continues to be forced by the existence of open access to information. The increasingly competitive market conditions force every company to create superior and competitive strategies both in the short and long term [1]. The company dealing with this situation will not succeed without superior human resources who can contribute to the realization of the company's targets and goals. In addition, changes in the situation and technology that are running very dynamically and massively can affect the operating system and bureaucracy in the management of a company, especially the company's human resource management, where the resources owned by the company must have qualified capabilities to help the company to create a competitive advantage. In companies that are categorized as labor-intensive companies, human resources are a vital asset for the company because apart from serving as operational executives, human resources or employees in a company can be a source of business ideas [2]. Furthermore, based on several studies, it turns out that the biggest challenge for all companies, especially those that are labor-intensive, is how to create strategies that can improve employee performance individually or collectively so that they can contribute to or have an effect on the company's overall performance [3]. In a working system in a company, human resource management plays a very important role in improving the skills, creativity, knowledge, and abilities of employees that can support the success of employee performance [4]. Besides, the success of the company is not only measured by how much profitability is generated by the company but is also measured by the increase in the number of skilled and productive employees in every work activity carried out [5]. Amid this phenomenon, it is very necessary to have a theoretical foundation that can be used as a basis for analyzing and understanding the situation (interaction patterns, performance, satisfaction, work climate, organizational culture, leadership style, etc.) of employees in a company.

The need for appreciation is often a complaint of employees working at every level of management. Understanding job satisfaction is very important for management to foster employee loyalty. The ability to appreciate every employee sacrifice is expected by everyone. Being involved in existing activities in the company and being made employees as company assets is the basis of job satisfaction (Newstrom, 2007). Job satisfaction can also be seen in whether an employee is happy or not from the remuneration he receives (Robbins & Judge, 2012). Dissatisfaction will arise when the compensation provided by this company does not meet employee expectations (DeCenzo et al, 2016). Emotional feelings are the basis for measuring an employee's job

satisfaction with various aspects of his work. Every employee can be satisfied with his job when he can control his emotions. Employees are satisfied with work when they can adjust to their interests. Employees will try to be positive about aspects of their work environment. Furthermore, the company will continue to measure job satisfaction as feedback on the remuneration that has been provided (Bernardin & Russel, 2013). This goal is necessary so that employees retain their best performance in completing the task load for which they are responsible.

Employee creativity is something that an employee must have in carrying out any given job, even in various studies it has been found that creativity is something that is inherent and has the potential to continue to develop within a person [6-10]. The higher the level of creativity possessed by an employee, the more optimal the work results that can be achieved. Besides, the creativity possessed by an employee can also help him to solve work problems more quickly in different ways but still by the work regulations set by the company [11,12]. In the development of organizational behavior, the level of creativity possessed by an employee can also be formed from patterns of interaction that occur in the work environment and can further form collective creativity [13]. The essence of employee creativity is how to optimize the power and potential of employees so that they can be productive to realize the goals that have been determined by company management. In companies that are oriented to or engaged in creative industries and technology, the level of employee creativity becomes very important because having employees with a high level of creativity will help the company to grow and can further help companies to create new products that can improve the competitive advantage of the company [14]. In addition, in labor-intensive companies such as companies engaged in the industrial sector: manufacturing, plantation, construction, and transportation, employee creativity also plays an important role because by having employees with a high level of creativity each job can be completed more quickly and optimally without regular supervision of the work activities of each employee is required [15]. In general, employee creativity is defined as the ability of employees to find and implement new perspectives to get new ideas and have an impact on the company and company achievements [16,17]. Furthermore, Deal (2007) it is stated that employee creativity is the capability of an employee to create ideas or ideas, while Glăveanu (2013) states that employee creativity is the result of an imagination process that encourages someone to find new ideas.

Leadership studies continue to experience rapid development. Transformational leadership is currently still not widely studied specifically in the development of human resource studies. Initially, the theory of leadership was initiated by James Mac Gregor Burns (1979) [18] which was further developed by Bernard M. Bass (1985) to become Leadership and Performance Beyond Expectations. The study emphasizes that transformational leadership is one of the main ideas. According to [19] transformational leadership seeks to guide each individual and team to work beyond status. A transformational leader is someone who has the power to bring about change in the members of the team and the organization as a whole. The term transformational leadership is an attempt by leaders to transform followers from one lower level of need in the hierarchy of needs to another higher level of need [20].

The agricultural sector is one sector that cannot be underestimated because the lifeblood of a country's economy depends on agriculture both in the short and long term. Agriculture has a substantial nature in terms of development because it can act as a fulfillment of food needs, a provider of raw materials for industry, a contributor to foreign exchange, and a provider of employment [21]. The ability to achieve production in PT. Perkebunan Nusantara III, of course, through optimizing employee performance. This research is considered important considering that the performance of employees specifically at this Indonesian-owned company is known for its relaxed culture and lack of work responsibilities [22]. In a working system in a company, human resource management plays a very important role in improving the skills, creativity, knowledge, and abilities of employees that can support the success of employee performance [4]. Besides, the success of the company is not only measured by how much profitability is generated by the company but is also measured by the increase in the number of skilled and productive employees in every work activity carried out [5]. Amid this phenomenon, it is very necessary to have a theoretical foundation that can be used as a basis for analyzing and understanding the situation (interaction patterns, performance, satisfaction, work climate, organizational culture, leadership style, etc.) of employees in a company. The agricultural sector is one sector that cannot be underestimated because the lifeblood of a country's economy depends on agriculture both in the short and long term. Agriculture has a substantial nature in terms of development because it can act as a fulfillment of food needs, a provider of raw materials for industry, a contributor to foreign exchange, and a provider of employment. The ability to achieve production in PT. Perkebunan Nusantara III, of course, through optimizing employee performance. This research is considered important considering that the performance of employees specifically at this Indonesian-owned company is known for its relaxed culture and lack of work responsibilities.

2 Methodology

The design of this study is quantitative research. Data were collected by distributing questionnaires with a Likert scale to a sample of 230 employees at PT. Perkebunan Nusantara III was selected using a non-probability sampling technique (Sugiono, 2015: 84). Furthermore, the

data were analyzed using the Structure Equation Model (SEM) based on Partial Least Square (PLS) which aims to determine the direct and indirect effects between variables. This SEM-PLS method was used to determine the direct effect of the variables of employee creativity, transformational leadership, and job satisfaction on employee performance and the indirect effect of the variables of employee creativity and transformational leadership on employee performance through job satisfaction. According to Sholihin & Ratmono (2013), SEM-PLS can work efficiently on complex models. In addition, the assumption of data distribution in SEM-PLS is relatively looser than that of CB-SEM. In addition, SEM-PLS is a nonparametric approach that can work well even for data that is not normally distributed extremely. Furthermore, the Partial Least Square (PLS) method was carried out in this study with the following stages:

a) The first stage is to test the measurement model (Outer Model), which is to test the validity and construct reliability of each indicator.
b) The second stage is to test the structural model (Inner Model) which aims to determine whether or not there is an effect between variables/correlation between the constructs measured in this study.

3 Result and discussion

Measurement Model Analysis (Outer Model)

Convergent Validity Test

Based on Figure 1, the value of the loading factor for all indicators in the model was greater than 0.7. So it can be concluded that it was reliable for the measurement of the research variables. Then it can be used in the next analysis.

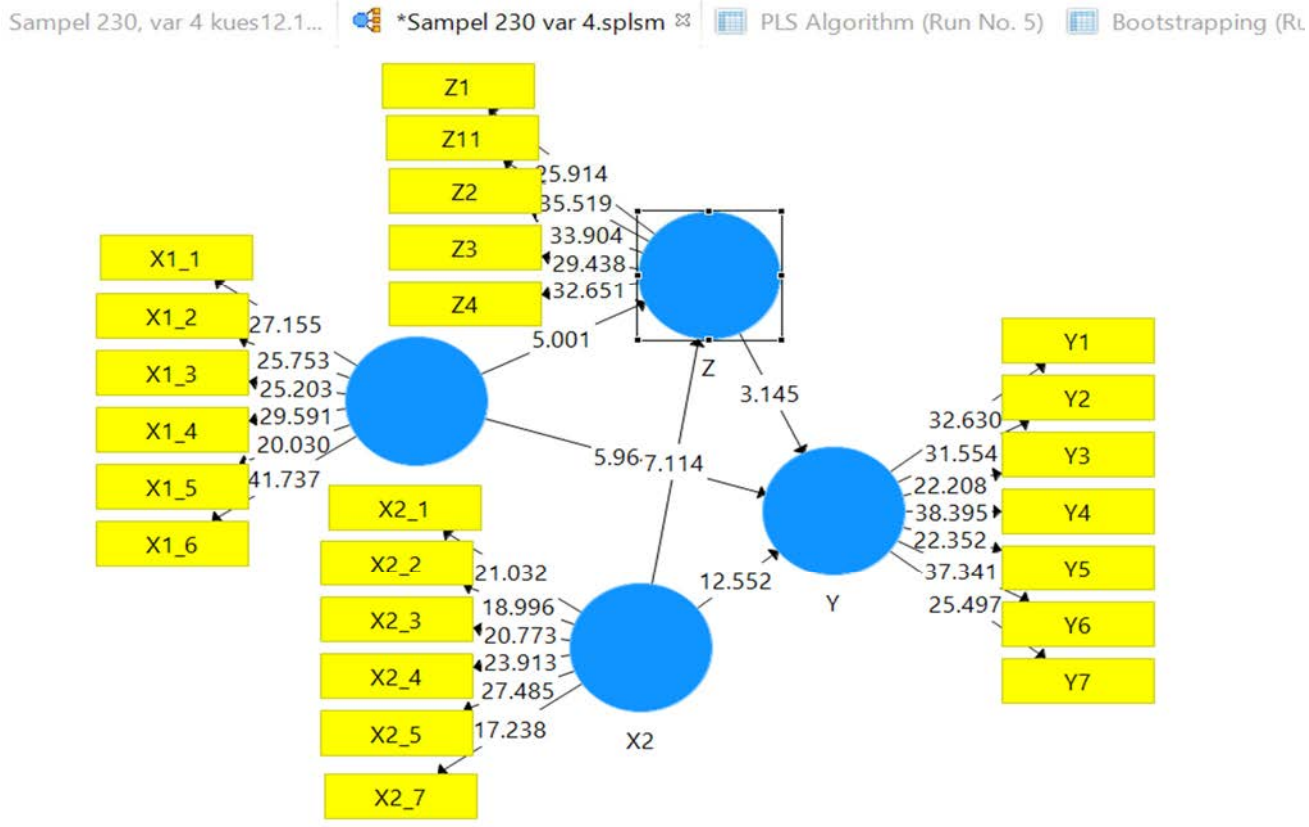


Figure 1 The value of loading factor of indicators for all variables

Construct Reliability Test

The results of data processing are shown in Table 1 below.

MODELS OF IMPROVING EMPLOYEE PERFORMANCE AND JOB SATISFACTION IN PT. PERKEBUNAN NUSANTARA III

Fazar Rezeki Ananda Fajar; Syaifuddin Syaifuddin; Sofiyan Matondang

Table 1 Construct reliability

Sampel 230, var 4 ... | *Sampel 230 var 4.... | PLS Algorithm (Run... | Bootstrapping (Run...

Construct Reliability and Validity

Matrix	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
X1	0.879	0.881	0.909	0.624
X2	0.864	0.865	0.899	0.596
Y	0.898	0.900	0.919	0.620
Z	0.876	0.877	0.910	0.669

Measurement Model Analysis (Inner Model)

Coefficient of Determination (R2)

Based on the results of the calculations in Table 2, it is known that the value of R Square Adjusted for the employee performance variable is 0.921 or 92.1% while the remaining 7.9% is influenced by other variables not examined in this study. From the same table, the value of R Square Adjusted for the job satisfaction variable is 0851 or 85.1% while the remaining 4.9% is influenced by other variables not included in this study.

Table 2 Value of R Square

Sampel 230, var 4 ... | *Sampel 230 var 4.... | PLS Algorithm (Run...

R Square

Matrix	R Square	R Square Adjusted
Y	0.922	0.921
Z	0.853	0.851

Hypothesis Test

Based on Table 3, it was indicated that the average value is more than 0.5. Then the composite reliability value was more than 0.7. So it can be concluded that the indicators in this study were able to measure well.

Table 3 Direct effects

Sampel 230, va... | *Sampel 230 v... | PLS Algorithm (... | Bootstrapping (... | Bootstrapping (...

Path Coefficients

Mean, STDEV, T-Values, P-... | Confidence Intervals | Confidence Intervals Bias ... | Samples | Copy to

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistic...	P Values
X1 -> Y	0.305	0.303	0.053	5.812	0.000
X1 -> Z	0.389	0.393	0.076	5.127	0.000
X2 -> Y	0.535	0.537	0.042	12.679	0.000
X2 -> Z	0.553	0.549	0.076	7.294	0.000
Z -> Y	0.144	0.145	0.047	3.089	0.002

Effect of Employee Creativity on Employee Performance

The results of testing and analysis of research data can be stated that the creativity of an employee has a major impact on increasing the quality and quantity of work. The results of this analysis are in line with previous studies which state that the ability to solve problems possessed by employees can reduce the rate of work errors [20] it was also found that companies that have employees with high creativity will help companies to find new products. Similar results are also shown by studies of [23,24] which indicate that a strong work team will ultimately be able to encourage innovation that has an impact on new work and creates a shorter work bureaucracy.

Effect of Transformational Leadership on Employee Performance

The results of data processing show that this transformational leadership is considered effective in supporting an employee's morale. Employees feel motivated by the transformational leadership model that exists at PT. Perkebunan Nusantara III. Furthermore, these results reinforce the results of previous studies which emphasize that transformational leadership is able to improve employee performance. Studies conducted by [18] also show that leaders who have a transformational leadership style can stimulate employees to work more effectively, innovatively, optimally, and by the targets set by the company. Similar results are also shown by studies by Rafferty & Griffin [25,26] which state that a leader who has a transformational leadership style will encourage employees to have a high work ethic and comply with regulations.

Effect of Employee Creativity on Job Satisfaction

Based on direct data analysis, it can be concluded that employee creativity has a significant effect on employee performance. This is known from the significance value of the employee creativity variable of 0.000 which is smaller than 0.05. This means that employee creativity has a significant effect on job satisfaction at PT. Perkebunan Nusantara III is a study conducted by [27] which states that employee creativity has a significant effect on job satisfaction. This result is also in line with the study conducted by [28,29] which states that creativity is inseparable from job satisfaction.

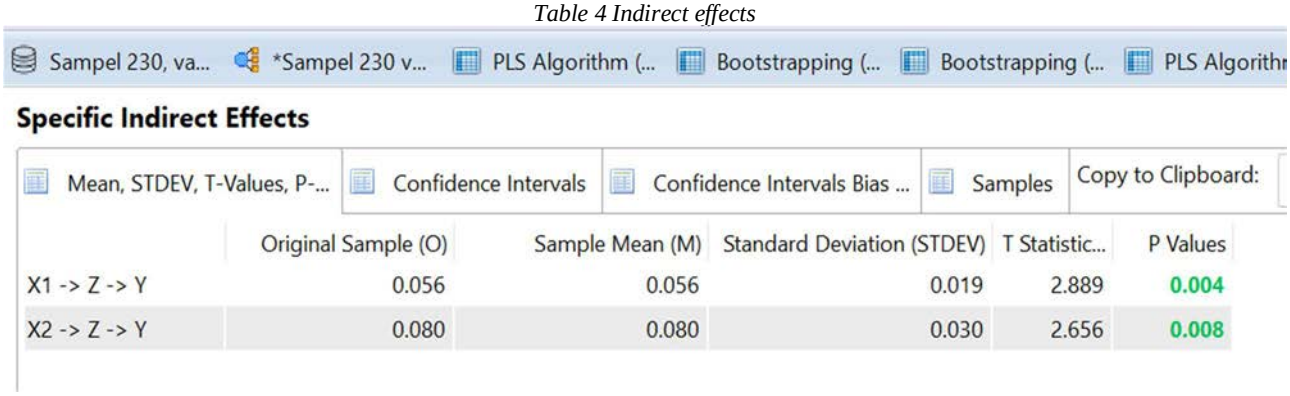
Effect of Transformational Leadership on Job Satisfaction

Based on direct data analysis, it can be concluded that transformational leadership has a significant effect on employee performance. This is known from the significance value of the transformational leadership variable of 0.000 which is less than 0.05. The results of this study are in line with the results of a survey conducted by [30] which stated that the leader had a very large effect on job satisfaction. Similar results were also found in a survey conducted showed that leadership had a significant effect on job satisfaction. The survey by [31,32] also states that transformational leadership has a significant effect on job satisfaction.

Effect of Job Satisfaction on Employee Performance

In direct data analysis, it can be concluded that job satisfaction has a significant effect on employee performance. It is known that the significance value of the job satisfaction variable of 0.000 is smaller than 0.05. The results of the study of [33] show that based on partial least squares job satisfaction has a positive but not significant effect on employee performance. Good job satisfaction directs every employee to give their best in completing the tasks assigned by their superiors [34,35].

Table 4 Indirect effects



Specific Indirect Effects

Mean, STDEV, T-Values, P-... | Confidence Intervals | Confidence Intervals Bias ... | Samples | Copy to Clipboard:

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistic...	P Values
X1 -> Z -> Y	0.056	0.056	0.019	2.889	0.004
X2 -> Z -> Y	0.080	0.080	0.030	2.656	0.008

Effect of Employee Creativity on Employee Performance through Job Satisfaction

The results of testing the data show that job satisfaction has an indirect role in mediating employee creativity on employee performance at PT. Perkebunan Nusantara III. The implications of the findings in this study prove that opportunities in developing ideas in solving problems. This is considered capable of increasing the sense of job satisfaction of employees. This study proves these results are in line with the results of previous research which

concluded that the job satisfaction factor that exists in employees can indirectly provide encouragement for work creativity in improving their performance [28,36,37].

Effect of Transformational Leadership on Employee Performance through Job Satisfaction

Indirect data testing shows that transformational leadership is integrated in improving employee performance on the role of job satisfaction at PT. Perkebunan Nusantara III. The implications of the findings show that the leadership capabilities in PT. Currently, Perkebunan Nusantara III has been able to build a solid working team. Existing activities always involve their subordinates. The results of this study are in line with the results of the study [38-40] conducted which states that the company's ability to give birth to leadership regeneration is able to increase the sense of job satisfaction of employees and have an impact on employee performance

4 Conclusion

The conclusion that researchers got from the results of data analysis and discussion is that it can be stated that all independent variables in this study employee creativity, transformational leadership, and job satisfaction directly have a significant influence on employee performance. Lastly, in this indirect effect, it can be seen that job satisfaction has a significant role in mediating employee creativity and transformational leadership on employee performance at PT. Perkebunan Nusantara III, Sumatera Utara.

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CREATING A MODEL OF THE PRODUCTION HALL USING 3D PRINTING

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Keywords: SolidWorks, Twinmotion, 3D tlač, KISSlicer.
Abstract: The aim of this article is to create a scale model of the production hall using 3D printing as a visualization tool. The article describes the process of creating and preparing 3D models in the SolidWorks modelling program. Visualization is handled by Twinmotion architectural software, where the production hall also includes a machine park approaching the real image of the original hall.

1 Introduction

For the production of the 3D model, we chose the production hall of a company based in Bardejov, which deals with the execution of orders for the engineering industry and locksmith production. After a thorough familiarization with the premises of the production hall and the adjacent objects in which spraying, paint application, and chipping of the surface of materials and material warehouses are carried out, they took pictures of the individual spaces. After taking photos of the production premises of the hall and the land, we set ourselves the goal of creating a 3D model of the main production hall with machinery in order to effectively fill the space and present the company's basic machine park.

Design of the hall

We used the SolidWorks program to create individual models. In total, the hall consists of several machines: scissors, small scissors, a press, a bending machine, 2 saws, a stand drill, a grinder, a lathe, 4 tables, and 4 screens, the overall structure of the bridge crane, and including bridge pillar with rails, winch and hook. All models were drawn simply and then printed separately for better printability. At the initial stage of the creation, it was important to create the area of the plot so that we could lay out the individual buildings with the hall and the fencing of the plot. After measuring and correcting the creation of this land area, we started with the creation of the hall itself, to which we will later add offices. The hall itself has dimensions of 510 mm in length and 360 mm in width. After modelling, we added windows as in the original plan of the hall. When we modelled the hall, we started to create individual machines (Figure 1).

The process of creating a physical model using 3D printing

After the overall creation of the models and all the parts of the hall, we checked all the models afterward so that we would not have a problem connecting them when they were printed. Subsequently, we could save the models in STL format, which need to be created and used for processing in our chosen Kisslicer. The transformation of STL files is possible in this program created in 3D software, in our case SolidWorks, to the necessary gcode for printing. We also use this program to enter the necessary information for printing (Figure 2), which was performed on the TRILAB DeltiQ 2 and TRILAB DeltiQ 2 Plus printers.

After approval and checking of all parameters, we proceeded to print individual models. After completing all the actions necessary to start printing, we entered the already generated gcode into the printing process. We then waited to see if all the values we had chosen would be reached. In some cases, it was necessary to increase the temperature of the nozzle and the printing pad due to system incompatibility. Each model had a different print time and differed in the amount of filament used. Each model had to be cleaned of support without which it would we were not able to print these models.

When creating the model of the hall, we used plexiglass with a thickness of 3 mm. After cutting the plexiglass, we got 2 side walls with dimensions of 350x300 and another 2

walls with dimensions of 506x300. The floor plan of the hall has dimensions 500x350 mm (Figure 3).

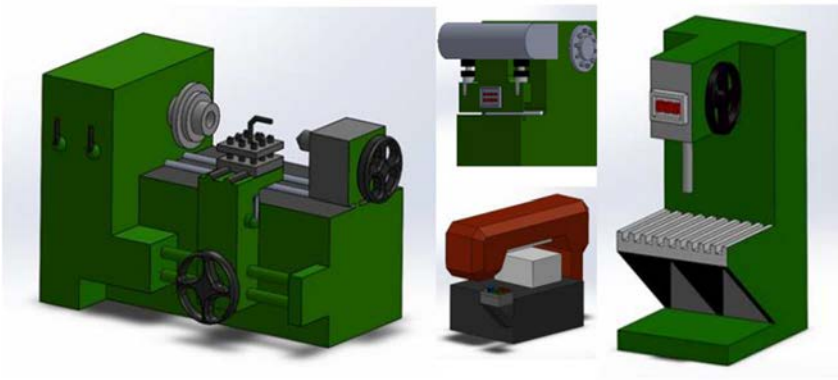

Figure 1 Modelled machines

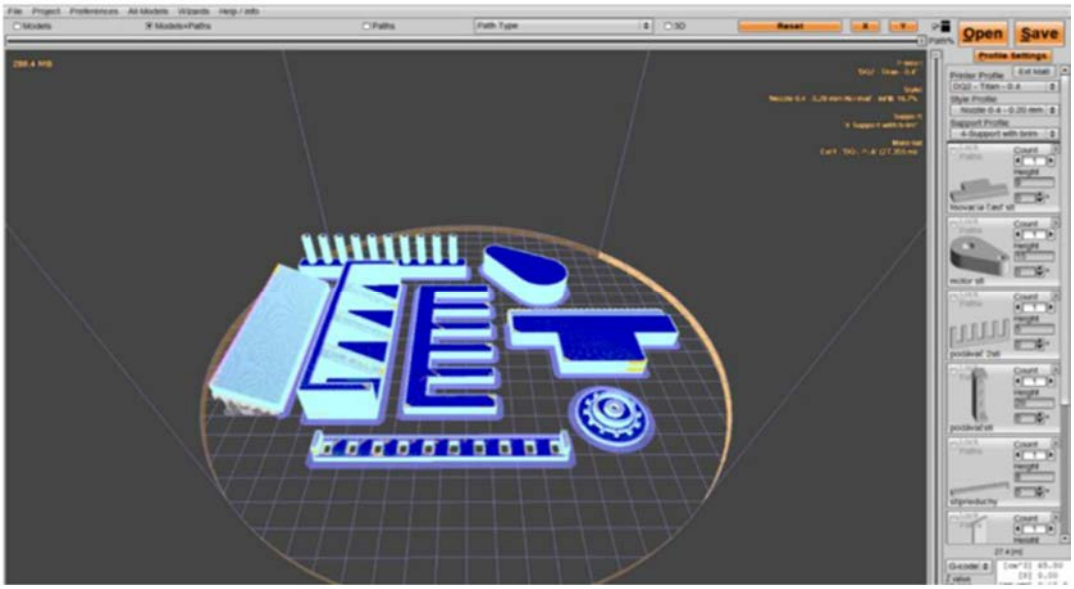

Figure 2 Working with models in the Kisslicer program

Figure 3 The printing process and the final model of the hall

Creation of visualization

During visualization, we gradually started with the creation of a hall with machines and then with the creation of the entire complex. We used models that were created in SolidWorks and then transformed into obj. format so that we can subsequently transfer the models to the TwinMotion program and gradually start editing them (Figure 4). TwinMotion is a 3D architectural visualization software that takes us into virtual reality in real-time. It allows us to create high-quality images of our work, but also to be transported into this reality with the help of 360° VR videos, which are made in high quality and the rendering time is significantly shorter compared to other software. Another option is to enter the already created simulation environment with the help of VR glasses at any time according to our choice. In addition to a lot of editing and post-production of the environment, Twinmotion has a wide range of materials that really respond to the set lighting conditions of the scene with their display.

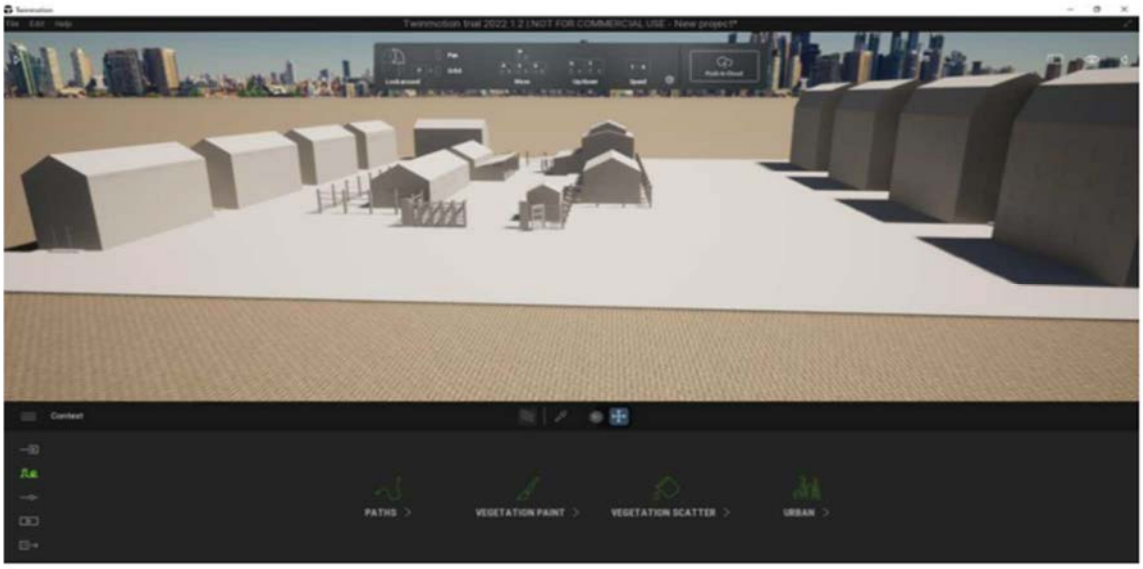

Figure 4 Initial model of the hall

After transferring this whole complex to our environment, it was necessary to solve the bad orientation of the object with respect to the basic position. In our understanding, the object was perpendicular to the surface of the virtual environment. After studying the individual actions, we dealt with them and redirected the given model to a horizontal position. After orienting the object, we could proceed with the subsequent modifications of the surface, where we added the stone structure to it (Figure 5). Finally, we dealt with the remaining buildings (Figure 6).

Figure 5 Model of the hall and its interior

Figure 6 Visualization of the entire complex

2 Conclusions

The article presents the production of the production hall and its machinery. The article defines the production of 3D models of the machinery park. The individual models were made by the Rapid prototyping method with the FDM - Fused Deposition Modeling 3D printing method. The models were created in SolidWorks. In the process of creating 3D models, it is necessary to transport models from the SolidWorks program in the correct format, namely the stl format. In Kisslicer, we have set the printing parameters and properties. TRILAB DeltiQ 2 PLUS and TRILAB DeltiQ XL 3D printers were used to print machine models in the production hall. We chose the material for printing the models PLA and PET-G. After printing the models, we removed the support from all parts and then joined the individual models with the help of glue. We stacked the subsequent models in a plexiglass hall made by us, reinforced with the help of modelled L-profiles. Last but not least the council should not forget that in addition to the physical model of the hall, we also created its visualization. For this we used Twinmotion. The main advantage of creating this building with a hall is the possibility of using a large number of materials that this program offers in the library.

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